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SOME ECOLOGICAL ASPECTS OF ZYUSAN-GATA WITH SPECIAL REFERENCE TO THE HABITATS OF *CORBICULA JAPONICA* GROUP

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The Inlet Zyusan-gata, situated near the apex of the Tsugaru Peninsula, Aomori Prefecture, is about 18.5 Km^2 in area. It is connected with the Japan Sea through a narrow strait opening north-westward, which is about 300 m in length and about 100 m in width. The Rivers Yamada and Iwaki empty into this inlet in the south and south-eastern coast respectively as the main rivers. The general shape of the Zyusan-gata is shown in Fig. 1.

In this inlet, Tamura (1952, 1953) has reported mainly on seasonal change of chemical characters of the inlet water, and pointed out that the salinity of inlet water had comparatively high concentration from early summer to late autumn, however, from winter to spring it became nearly zero. As a result of this observation, he concluded that this phenomenon had a controlling influence on the survival of the animal habitants in this inlet.

In the Zyusan-gata the commercial fishing of the clam (*Corbicula japonica*) has been prosecuted for many years and, as shown in Table 1, the annual production of

Table 1. *Yamatosizimi* (*Corbicula japonica*) and other aquatic products processed in Zyusan-gata, 1944 to 1953

Year	*Yamatosizimi*		Other aquatic products	
	Yield	Value of products	Yield	Value of products
	*Kan**	*Yen*	*Kan*	*Yen*
1944	40,000	400,000	35,700	3,860,000
1945	60,000	600,000	30,700	3,290,000
1946	100,000	1,000,000	28,500	3,180,000
1947	100,000	1,500,000	20,300	3,240,000
1948	100,000	1,500,000	17,300	2,690,000
1949	150,000	3,000,000	15,700	2,560,000
1950	130,000	2,600,000	13,200	2,110,000
1951	150,000	3,000,000	11,200	1,760,000
1952	130,000	2,600,000	7,700	1,200,000
1953	120,000	2,400,000	3,800	580,000

* 1 *Kan* is about 3.75 Kg.

this clam amounts to about 120000 *Kan* (about 480 tons). From the above table it will be noticed that the clam fishery has been of very great economic importance to fishermen because it is the only stable fishery that they engage in. Consequently,

that point should be mentioned first in reporting on the ecology of Zyusan-gata with reference to the environmental conditions of the habitat of the clam, although the clam fishery is also vitally interested in various aspects of the ecology of *Corbicula japonica*. In this paper is reported the general ecology of this inlet together with some information on bottom material and benthic animals.

Before proceeding further, the author expresses his heartly thanks to Prof. T. Tamura of the Faculty of Fisheries, Hokkaido University, for his guidance throughout the work. He is also grateful to Mr. T. Banba, Chief of Zyusanmura Fishermen's Association and Mr. S. Kudo of the Aomori Fisheries Experimental Station, for their help of various sorts in collecting the samples in Zyusan-gata.

The present work was carried out with the financial aid of a subsidy for Fisheries Research from the Aomori Prefectural Office.

Method

Survey stations are indicated in Fig. 1, namely 62 stations designed lattice-like being at about 500 m interval from each other. The observations covered the period from Oct. 4, to Oct. 7, 1953, during which measurement of depth, collection of bottom material and quantitative samples of clam were made all stations while quantitative collections of benthos and water samples were made at the 28 stations shown in Fig. 1, as solid circles. Water samplings at these stations were made from bottom layer at 0.1 m above the bottom by Tamura's water sampler. The chlorinity was determined by titration with silver nitrate.

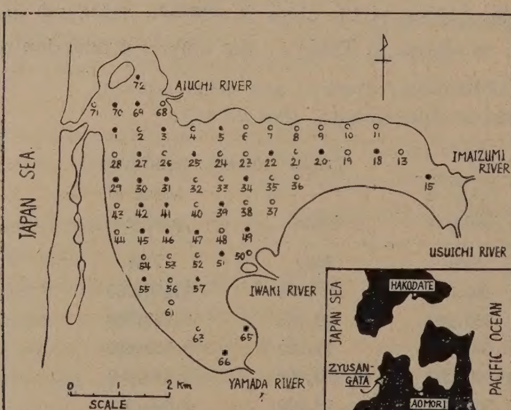


Fig. 1. Sketch-map of Zyusan-gata showing stations of observation

The bottom material was collected with Ekman-Birge type bottom snapper. The bottom samples, after drying, were analysed by the Turin method for organic carbon, and the total nitrogen contents were determined by the Kjeldahl method. The particle size was measured by the Beaker method as follows: viz. gravel (particle diameter over 2 mm), coarse sand (2-0.3 mm), fine sand (0.3-0.05 mm), silt (0.05-0.01 mm), and clay (less than 0.01 mm).

In order to observe the benthos the following operations were repeated at the various stations. The bottom material was quantitatively sampled by Ekman-Birge type bottom snapper of 120 cm^2 area and was sifted out by a wire net with 15 meshes to the linear inch to remove mud and sand. As the next step, the animal specimens

left in the sieve were fixed with about 5 % formalin; the number of individuals of each species was counted and these data were recorded per m^2.

Result

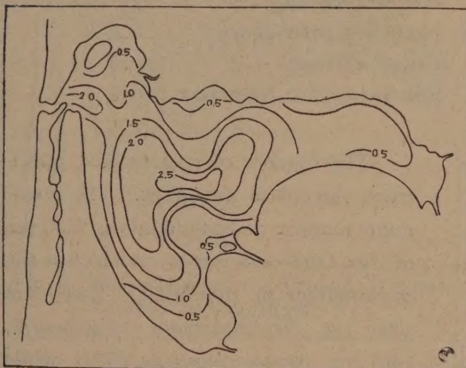


Fig. 2. Depth of water in Zyusan-gata

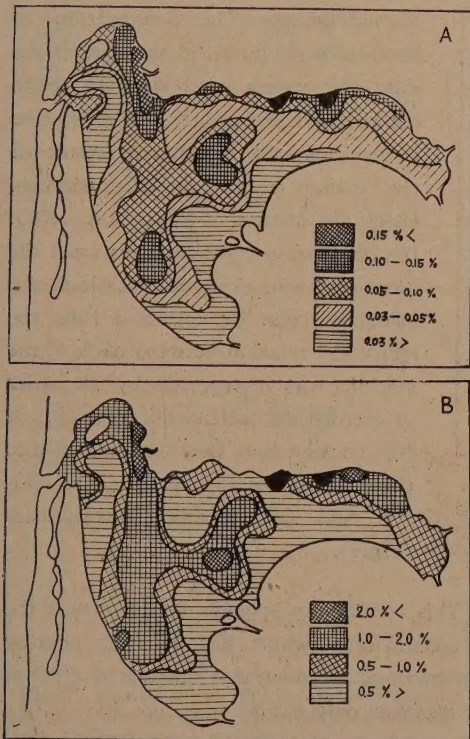
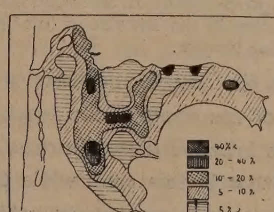


Fig. 3. Distribution of chemical elements in the bottom material
A and **B** indicate distribution of total nitrogen contents and organic carbon contents respectively.

Bottom material : Generally, the depth of water shows an average of less than 1.5 m, although both the central part and the mouth of strait form a deeper basin with maximum depth of approximately 3.0 m. The channel of the River Iwaki projects toward the central part of inlet near its estuary. A shallow part that is called *Okinose* including St. 24 & 25 also approaches to the central part of the inlet. Such tendency concerning the shallowness in the central part increases suddenly (Fig. 2).

Horizontal distribution of organic carbon and total nitrogen contents of the bottom material are shown in Fig. 3. In Fig. 4, percentage of the particles of less than 0.05 mm diameter against the total composition of the bottom material of all stations is presented. Maximum contents are 40 and 20 % near the south-eastern coast and the central part; these areas have considerably high contents in organic carbon and total nitrogen in comparison with others.

The substratum of the shallow areas which occupy the innermost at the inlet is formed of sandy mud, so that these areas provide favourable substratum conditions as the clam field.


Fig. 4. Distribution of the particles of less than 0.05 mm diameter (silt & clay) in the bottom material

Benthic communities : The composition of benthos collected by Ekman-Birge type bottom snapper with an opening of 120 cm^2 at the 28 stations during the above term in this inlet is as follows:

Corbicula japonica	48.3 %	*Paranthura* sp.	1.3 %
Anisogammarus kygi	20.7	*Neomysis intermedia*	0.8
Neosphaeroma oregonensis	19.6	*Crago affinis*	0.5
Assiminea septentrionalis	6.7	*Semisulcospira libertina*	0.3
Nereis japonica	1.8		

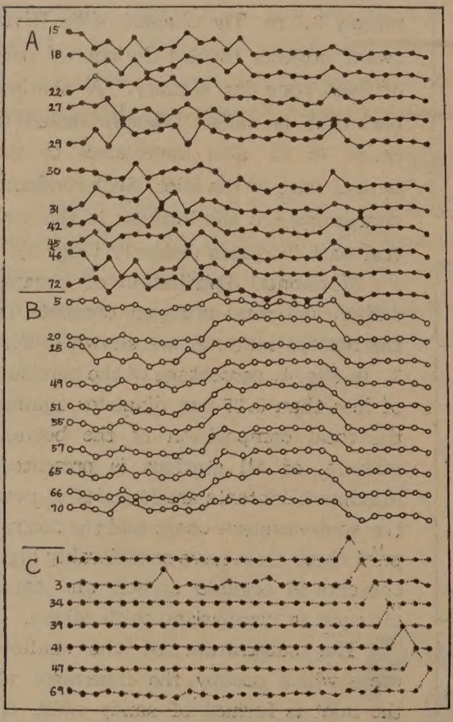


Fig. 5. Series of correlation coefficients of the benthic composition showing the reciprocal relation between the stations. Numbers in the left side of this figure indicate station number.

The number of species and specimens thereof is not great. The maximum number of individuals is 2750 per m^2 for *Corbicula japonica* which is the predominant in this inlet. There are 2080 for *Neosphaeroma oregonensis*, 1580 for *Anisogammarus kygi*, while other species were small in the number of individuals. The composition of benthos is not uniform throughout the inlet, but varies with stations. Such composition of benthos at each station is regarded as a cumulative result of the various environmental conditions. Using the method of Motomura (1936), the correlation coefficient between the composition of every two stations was calculated one by one and thus the reciprocal relation between each of the stations was represented by 28 series of correlation coefficients (Fig.5). It will be seen that they are divided into three groups by their forms, viz. (A), (B) and (C) benthic communities (Fig.6).

The first benthic community is (A). This community spreads out from near the mouth of the strait to the north-western coastal area, which has no river pouring into the inlet. *Anisogammarus* and *Neosphaeroma* are dominant making 36.1 % of the benthos in this area, while *Corbicula* occupies only 8.3 %.

The second community which is situated near the estuaries of all rivers is assumed to contrast with the first community. This area has relatively abundant benthos totaling 65.1 % of the total benthic fauna in this inlet. Dominant species is

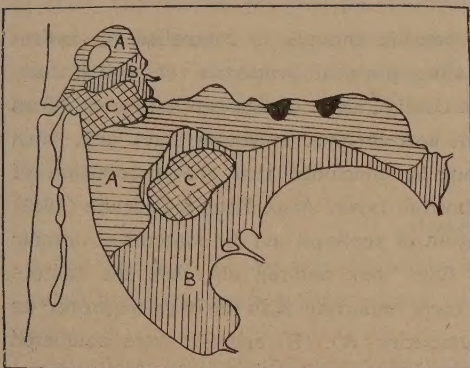


Fig. 6. Map showing the ground of three benthic communities

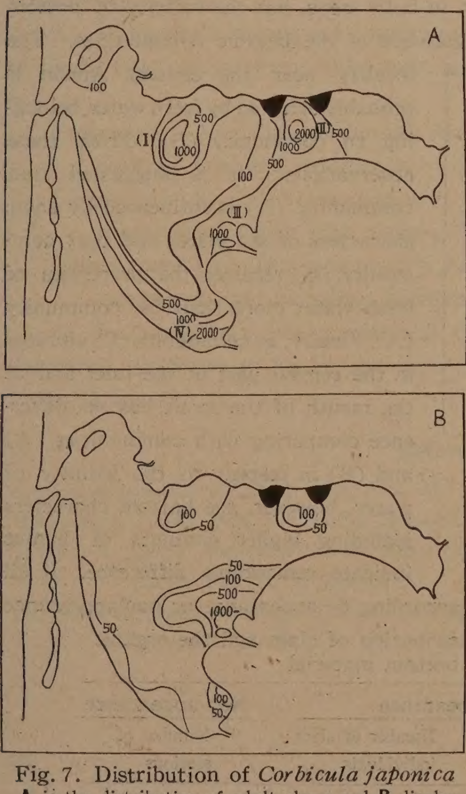


Fig. 7. Distribution of *Corbicula japonica*
A is the distribution of adult clams and **B** display the distribution of larval clams.

Corbicula japonica presenting 71.4 % of the benthic animals in this community, followed by *Anisogammarus kygi* with 12.7 %.

In the third community, benthos is lacking. *Nereis japonica* and *Crago affinis* were found in this area, which show only 0.5 % of the total benthic population in this inlet.

Among them, the horizontal distribution of clam is shown in Fig. 7, A. If the area holding more than 1,000 individuals of clam per m^2 is recognized as the main clam field in this inlet, there will be four areas, viz., areas I, II, III and IV. The distribution of larval clam also shows the same tendency as adult one (Fig. 7, B).

Discussion

On Oct. 4, 1953, the horizontal distribution of salinity was in agreement with Tamura's observation in Oct. 1950 (Tamura, 1953) (Fig. 8). According to Tamura (1953), even in the deepest part no difference was observed between the salinity of surface and bottom water, so it was assumed that the salinity of bottom water has the represented same fluctuation as the surface layer. In the Zyusan-gata, two channels run inward from the mouth of the strait; one is directed to the River Yamada, the other runs toward eastern area of the inlet through the central part. From the above configuration of salinity distribution (Fig. 8) it appears that the sea water inflows inward along these channels. Also, areas possessing abundant contents of humus and fine soil have been found in both channels; this is probably due to the slight particles precipitated by the stagnation

of the water through the channels.

It is believed that the distribution of benthic animals is controlled by hydrographic characters of bottom layer including physical properties of substratum. Yamamoto (1950, 1951) pointed out that the configuration of the benthic communities resembles the distribution of the salinity of bottom layer in Mutsu Bay, and, with that observation as a basis for his opinion, he concluded that the distribution of benthos was controlled by the salinity of bottom layer. Also, Kato & Ishizuka (1949) discussed the relation between the distribution of scallops and the contents of organic carbon in the bottom materials in Mutsu Bay; they pointed out that the factors related to the supplement of oxygen were more important than the physical properties of substratum. Accordingly, benthic communities (A), (B) and (C) were compared with the environmental conditions in Zyusan-gata.

In communities (A) and (B), the substratum is composed of sand or sandy mud and the depth of water is less than 1.5 m in both areas, but the salinity of bottom layer shows a fair likeness with the configuration of the benthic communities. The locality near the estuary Aiuchi is probably affected by fresh water belonging to community (B). From these observations, it is suggested that community (A) is influenced by some characters of sea water and that community (B) receives the properties of fresh water more than the community (A). Finally, in community (C) situated in the central part of the inlet and at the mouth of the strait has no difference comparing with communities (A) and (B) in respect to the salinity of water, however, the bottom characters including higher contents of humus indicate remarkable difference. If all stations are divided into two categories, according to appearance or non-appearance

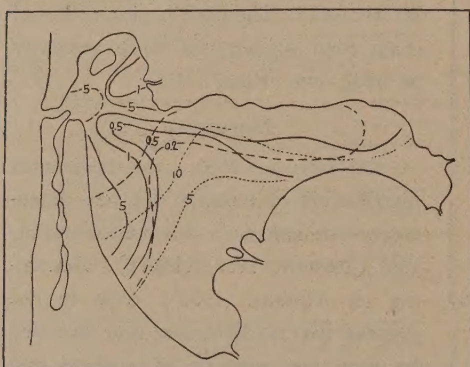


Fig. 8. Chlorinity distribution of the bottom water
Full line indicates the results on Oct. 4, 1953. Broken and dotted lines represent Tamura's observations obtained in Oct. 1950 and June 1948, respectively.

Table 2. Relation between the distribution of clam and the organic carbon contents of the bottom material

Contents of organic carbon	Appearance: Number of stations	Appearance: Number of clam individuals	Non-appearance: Number of stations
0.5 % and under	25	208	5
0.5-1.0 %	5	33	7
1.0 % and over	5	33	15
Total	35	274	27

of clam, the relation between the distribution of clam and the contents of organic carbon in the bottom material would show as is tabulated in Table 2. In the first case, the number of stations reporting the appearance of the clam and number of individuals of clam both increase with diminution of the organic carbon; on the other hand, they also increase in proportion to augmentation of the organic carbon in the bottom material.

Summary

1) Generally, in this inlet the water is mostly shallow of less than 1.5 m and in such area the humus content is poor, so that such areas form favourable clam fields.

2) *Corbicula japonica* is dominant forming 48.7 % of the composition in the inlet among the benthos; it is followed by *Anisogammarus kygi* 20.7 % and *Neospheroma oregonensis* 19.6 %.

3) Motomura's correlation coefficient method was employed for the discussion of the benthic communities. There were seen three communities as follows (Fig. 5 & 6):

Community (A) : This community receives influence of sea water, and *Anisogammarus kygi* and *Neosphaeroma oregonensis* are dominant species.

Community (B) : *Corbicula japonica* is dominant. This area is affected by fresh water more largely than community (A).

Community (C) : This community has few benthic animals; the substratum consists of mud including abundant organic humus.

4) In Zyusan-gata, the commercial fishery exploits *Yamatosizimi* (*Corbicula japonica*). As shown in Fig. 7, the main clam field is located in four areas, viz. areas I, II, III and IV.

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CONTRIBUTIONS TO THE KNOWLEDGE OF GRACILARIACEAE FROM JAPAN

I. Critical Notes on the Structure of *Gracilaria Textorii* (*SURINGAR*) *J. AG.*

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Gracilaria Textorii was first described from Japan by Suringar in 1867 under the name *Sphaerococcus* (*Rhodymenia*) *Textorii* in his "*Index praecursorius Algarum Japonicarum*". Okamura (1900) gave a detailed account of the plant, illustrating the structure of its cystocarp and tetrasporangium. On the other hand, *Gracilaria Vivesii* was described by Howe in 1911 in his "Phycological studies V. Some marine algae of lower California, Mexico", on the basis of an antheridial specimen and a sterile one obtained at La Paz, Baja California, Feb. 28, 1911 by G. J. Vives. In 1924 Setchell and Gardner added *G. Vivipara*, *G. sinicola*, and *G. Johnstonii* to the list of foliate *Gracilaria* from the Gulf of California, but they were subsequently shown by Dawson (1944) to be identical with each other and to be united under the name of *G. Johnstonii*. Afterward, Dawson (1949) studied *G. Vivesii* and synonymized *G. Johnstonii* under that species. At the same time he recognized, comparing his observations with Okamura's figures (1900), that *G. Vivesii* agreed very closely with *G. Textorii* in the habit of frond, in the presence of nutritive filaments in cystocarps, and in the semi-nemathecial structure of cortex in tetrasporic plants. So he suspected the identity of the two species, but could not settle the problem for lack of knowledge on antheridia of *G. Textorii*.

In November, 1954, the writer was able to collect many specimens of *G. Textorii* in the vicinity of Oshoro Marine Biological Station, Hokkaido University. They were found to include rather many individuals of male plant. This is believed to be the first discovery of the male plant of the present species from Japan.

Comparing the external and internal structures of the specimens of *G. Textorii* in the writer's hand with the illustrations of *G. Vivesii* given by Howe and Dawson, the writer could find no essential difference between them. The frond of *G. Textorii* appears occasionally to be somewhat more delicate, more proliferous, and more finely dissected than that of *G. Vivesii*. However, such differences may reasonably be considered as local.

So the writer was driven to the conclusion that *Gracilaria Textorii* and *G. Vivesii* are one and the same species.

Here the writer proposes to give a description of *G. Textorii* based on the specimens now at hand from various localities in Japan.

Gracilaria Textorii (Suring.) J. Ag.

Index praecurs. Alg. Japon., 1867, p. 4; Id., *Sphaerococcus* (*Rhodymenia*) *Textorii*

Suring., Alg. Jap., 1870, p. 36. *Gracilaria Textorii* (*SURING.*) *J. AGARDH*, Spec. Alg., III, 1. Epicr., 1876, p. 426; De Toni, Phyc. Jap. Nov., 1895, p. 27 n. 52; Id., Syll. Alg. IV, 1900, p. 449; Okam., Alg. Jap. Exsic. no. 13, 1899; Id., Illust. mar. alg. Jap., 1900. *Gracilaria Vivesii HOWE*, Phyc. Stud. V, 1911, p. 503–505; Dawson, Stud. Northeast Pacif. Gracilariaceae, 1949, p. 34-36. *Gracilaria Johnstonii SET. et GARD.*, Mar. alg. exped. Calif. Acad. Sci. Gulf Calif. in 1921, 1924; Dawson, Mar. Alg. Gulf Calif., 1944. *Gracilaria sinicola SET. et GARD.*, loc. cit., 1924. *Gracilaria vivipara SET. et GARD.*, loc. cit., 1924.

Japanese name: *Kaba-nori*.

Hab.: Growing on rocks and stones at or below low-water mark. In Oshoro Bay, growing abundantly on the rocks, often preferring sheltered places, usually about 30-60 cm below water surface, associated with other algae such as *Sargassum confusum*, *Lomentaria catenata*, *Gymnogongrus flabelliformis*, *Chondrus armatus*, *Champia parvula*, etc. It seems to mature in autumn, as found in Oshoro Bay.

Locality: Yanagihara, Takahama, Minatoyama, Mitsugahama, Ehime Pref., Shikoku; Kurihama, Misaki, Kanagawa Pref.; Kominato, Chiba Pref.; Himi, Toyama Pref.; Oshoro, Hokkaido. Rather common along the Pacific and Japan Sea coasts of the warmer part of Honshu, also found along Shikoku and Kyushu coasts.

Plants foliose, caespitose, rising from a common scutate disc, with a short subcylindrical stipe, soon expanding into the cuneate base of frond, irregularly dichotomously to flabellately lobed with broad linear patent segments whose axils are rounded; color dull- or brownish-red to somewhat yellowish or greenish. Frond flat, membranous to thick coriaceous, variable in size and shape, usually 4.7-18.5 cm high and 7-45 mm broad under the dichotomies when mature, with rounded or somewhat attenuated apices; thickness of frond is also variable, young plants being quite thin (240 μ), while old ones may be as much as 750-875 μ thick; margins smooth and entire, occasionally slightly undulate, normally non-proliferous but sometimes with more or less simple or branched proliferations; apical segments, 0.5 7 mm broad below the apex, sometimes end in blunt or ligulate, or sometimes in acute or bifid apices; in other cases, terminal segments are much slenderer and more pale in color than the remaining portion, being divided repeatedly in dichotomous manner. The following table shows the variability in the external appearance of the present alga.

Table 1. Range of variability in the external appearance of *Gracilaria Textorii* from various lacalities in Japan

No.	Reproductive phase	Locality	Date of collection	Length	Width	Thick-ness	Color of frond
1	sterile	Takahama	Aug. 13, 1953	4.7 cm	9 mm	μ	dull red
2	〃	Misaki	Apr. 7, 1944	8	13		yellowish red
3	〃	Ao	May 24, 1953	8	25		red
4	〃	Oshoro	Nov. 1, 1954	8.2	22	440	pink
5	〃	Himi	May 31, 1953	10	13		dull red
6	〃	Kawahara	June 10, 1953	10	19		dull red

7	tetrasporic	Takahama	Aug. 16, 1953	6	7		dark red
8	〃	Mitsugahama	Aug. 5, 1953	7	8		pale red
9	〃	Takahama	Aug. 13, 1953	7	15		dull red
10	〃	Oshoro	Nov. 1, 1954	7.6	15	385	pink
11	〃	Takahama	Aug. 16, 1953	8	11		red
12	〃	Oshoro	Nov. 1, 1954	9	22	630	dark red
13	〃	Oshoro	Nov. 1, 1954	9.5	20	560	brownish red
14	〃	Akitani	June 6, 1951	9.8	10		pale red
15	〃	Oshoro	Nov. 1, 1954	10	14	440	pink
16	〃	Oshoro	Nov. 1, 1954	10	25	700	pale red
17	〃	Oshoro	Nov. 1, 1954	10.2	21	512	pink
18	〃	Oshoro	Nov. 1, 1954	10.3	23	525	brownish red
19	〃	Oshoro	Nov. 1, 1954	11	13	385	pink
20	〃	Minatoyama	Aug. 22, 1953	11.5	9		yellowish red
21	〃	Mitsugahama	July 29, 1953	12	20		red
22	〃	Kurihama	June 7, 1951	15	23		dull red
23	〃	Kurihama	June 7, 1951	18	36		dull red
24	〃	Kurihama	June 7, 1951	18.5	35		dull red
25	cystocarpic	Mitsu	Aug. 21, 1953	7.5	9		pale red
26	〃	Takahama	Aug. 21, 1953	8.5	9		dull red
27	〃	Oshoro	Nov. 1, 1954	8.5	18	700	brownish red
28	〃	Takahama	Aug. 21, 1953	9	9		purplish red
29	〃	Takahama	Aug. 18, 1953	9.5	13		slightly greenish red
30	〃	Misaki	May 7, 1944	10	12		yellowish red
31	〃	Oshoro	Nov. 1, 1954	10.5	12	700	pink
32	〃	Oshoro	Nov. 1, 1954	11	20	700	dark red
33	〃	Yanagihara	Aug. 12, 1953	12	8		greenish red
34	〃	Himi	June 7, 1953	12	15		dull red
35	〃	Oshoro	Nov. 1, 1954	12.6	18	680	dull red
36	〃	Kominato	May 2, 1950	13	22		dull red
37	〃	Oshoro	Nov. 1, 1954	15	15	700	greenish red
38	male	Oshoro	Nov. 1, 1954	8.6	20	525	bull red
39	〃	Oshoro	Nov. 1, 1954	11	13	440	greenish red
40	〃	Oshoro	Nov. 1, 1954	11.4	15	525	dull red
41	〃	Oshoro	Nov. 1, 1954	11.5	20	512	dull red
42	〃	Oshoro	Nov. 1, 1954	11.5	28	560	brownish red
43	〃	Oshoro	Nov. 1, 1954	13	16	525	brownish red

Specimens except from Oshoro can not be exactly measured as they are dried materials.

Frond internally consisting of a prominent cellular medulla of large (230–400 μ in diam.) thin-walled (5-9 μ thick) cells, which are colorless in content; cortex normally made of a pigmented single layer of more or less anticlinally elongated cells, which in older parts become two-layered, measuring 5-10 μ long, 4 6 μ broad in transverse section, and $4.3\mu\times4.3\mu$ to $5.4\mu\times6.5\mu$ as seen from surface; subcortical layers of somewhat larger cells, containing more or less Floridean starch grains which

are 3-5 μ in diam. The transition from the large medullary cells to the small cells of the cortex is abrupt. Colorless hairs occasionally present on frond surface, measuring up to 320 μ long and 6 μ thick. Surface jelly thin. Tetrasporangia are densely scattered over both surfaces of the frond except the apical and the lowermost portions, ovate to elongate in shape, attaining $22\mu \times 13\mu$-$35\mu \times 28\mu$ in transverse section and $8.5\mu \times 8.5\mu$-$40\mu \times 22\mu$ in surface view, cruciately divided. They are bright red in color.

Sexual plants are heterothallic.

Cystocarps are hemispherical or almost globular, up to 1660 μ in diam., ostiolate, densely scattered over both surfaces of frond. Pericarp is thick, being constructed of many layers of cells, which are anticlinally elongated. The development of the gonimoblast results in the formation of a parenchymatous, subspherical, narrow-based dome, sometimes called placenta, nearly filling the cystocarpic cavity and keeping connection with the pericarp by means of numerous nutritive filaments. These nutritive filaments are irregularly shaped, 105-180 μ long, 10 20 μ broad. Outermost cells of the pericarp are red in color, 9-15 μ long, 6 9 μ broad, while inner ones are yellowish in color or almost colorless.

Carpospores are spherical or slightly elongated in shape, measuring $13\mu \times 9\ \mu$-$28\mu \times 22\ \mu$, having a red chromatophore in the central portion.

Male frond is sometimes distinguishable by its pale red color from others. Antheridia are borne abundantly all over the surfaces of frond, in superficial shallow saucer- or cup-like cavities or pits, 20 μ wide, 17 μ deep, surrounded by modified, pigmented cortical cells. Antheridial pits are formed at first solitarily, but later become confluent. Within the pits are found clusters of antheridial branches transformed from cortical cells. Spermatia are colorless, globular, mostly 2-3 μ in diam. as seen from surface.

The plant is coriaceous and brittle while fresh, but becomes tenacious upon drying. A fully grown plant adheres imperfectly to paper in drying.

In conclusion, the writer wishes to express his hearty thanks to Prof. Jun Tokida for his kind guidance. Sincere thanks are also due to Dr. E. Y. Dawson in the Allan Hancock Foundation, University of Southern California, for his kindness in giving the writer a large set of valuable material from his collection of the northeast Pacific Gracilariaceae and many copies of his publications, as well as for his useful informations and helpful suggestions. The writer is also thankful to Prof. S. Ueda and Mr. Y. Sakai for their assistance in various ways. The expense for pursuing the present study was partly defrayed by a Grant in Aid for Miscellaneous Scientific Research from the Ministry of Education.

Summary

1. In this paper is reported the discovery of male plant of *Gracilaria Textorii* in Oshoro Bay, Hokkaido.

2. After comparing the antheridial and other structures of *G. Textorii* with those of the Californian *G. Vivesii*, the writer came to the conclusion that they are one and the same species as has been suspected by Dawson (1949).

3. A thorough description of *G. Textorii*, including a table showing the range of variability in the external feature, is given on the basis of numerous Japanese specimens from various localities.

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Explanation of plates

Plate I. *Gracilaria Textorii* from Oshoro Bay

Fig. 1. Transverse section through a sterile frond × 420

Fig. 2. Surface view of tetrasporangial sori × 420

Fig. 3. Transverse section through a tetrasporangial sorus × 420

Fig. 4. Surface view of an antheridial frond showing only tips of modified cortical cells × 420

Fig. 5. Surface view of an antheridial frond showing confluent antheridial sori among large cortical cells × 760

Fig. 6. Transverse section through antheridial sori showing superficial, slightly depressed, antheridial pits × 760

Plate II. *Gracilaria Textorii* from Oshoro Bay

Fig. 1. Vertical section through a mature cystocarp × 48

Fig. 2. Detail in the enlargement and ramification of the fusion cell, seen as if dissected away from surrounding cells × 420

Fig. 3. Carpospores showing a stellate central body × 420

Fig. 4. Part of section through pericarp showing anticlinally elongated cortical cells × 420

Fig. 5. Nutritive filaments showing various shapes × 420

Plate III. *Gracilaria Textorii* from Oshoro Bay

Fig. 1. Habit of a mature tetrasporic plant × ca. 1/2

Fig. 2. Habit of a mature cystocarpic plant × ca. 1/2

Fig. 3. Habit of a mature antheridial plant × ca. 3/4

Plate IV. *Gracilaria Textorii* from Kurihama

Fig. 1. Habit of a young tetrasporic plant having typical shape; Kurihama, Kanagawa Pref., June 7, 1951 × ca. 3/4

Fig. 2. Habit of a mature tetrasporic plant having broad frond provided with many finely dissected proliferations; Kurihama, June 7, 1951 × ca. 2/3

Plate V. *Gracilaria Textorii* from Kurihama and Bahia Agua Dulce

Fig. 1. Habit of a mature tetrasporic plant having abundant proliferations; Kurihama, June 7, 1951 × ca. 1/2

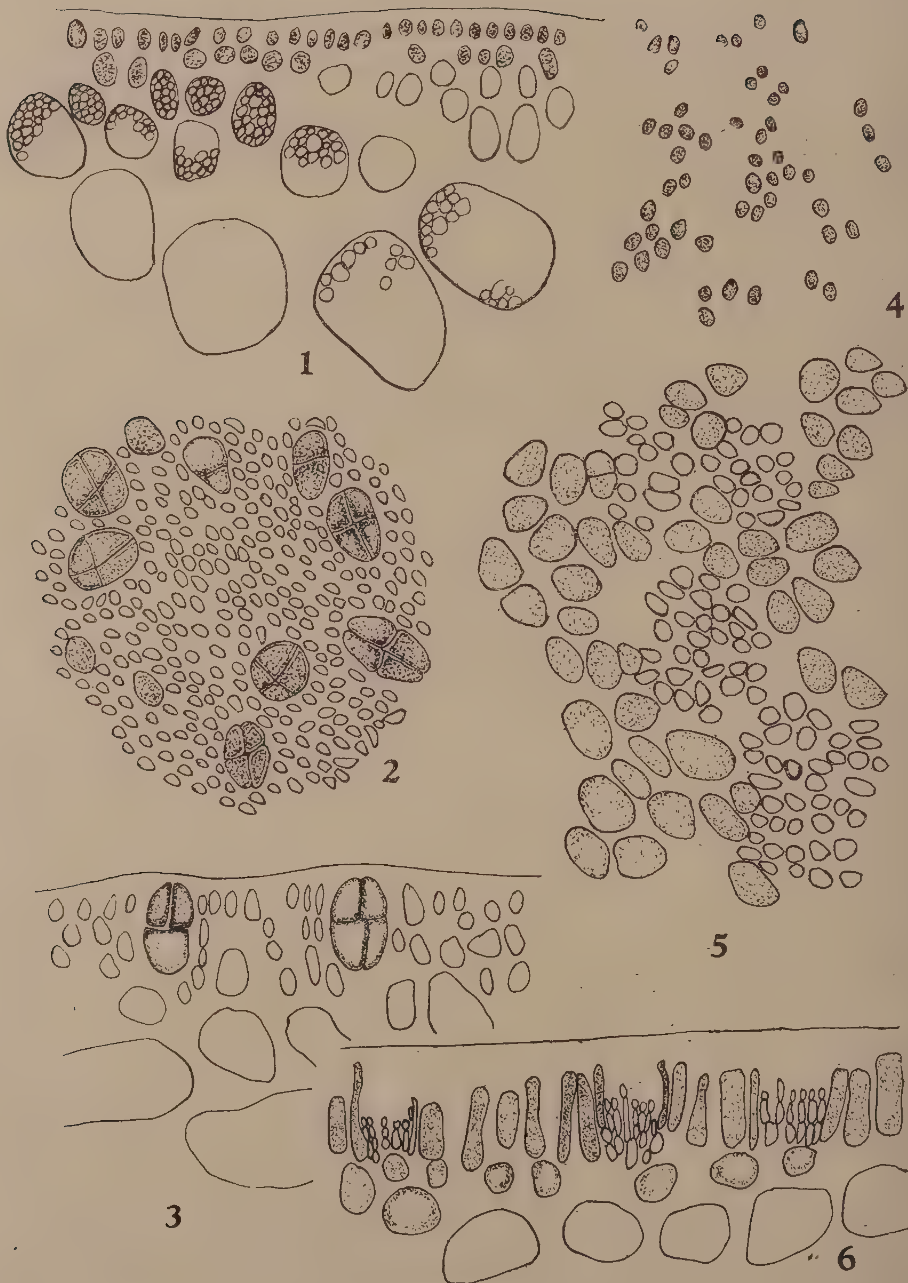
Fig. 2. Habit of a young tetrasporic plant showing typical mode of branching of a medium sized and slender frond; Bahia Agua Dulce, Isla Tiburon, Gulf of California, Dawson 877, Feb. 21, 1946 × ca. 3/5

Plate VI. *Gracilaria Textorii* from Bahia de Los Angeles and Ensenada Bocochibampo

Fig. 1. Habit of a sterile plant having broad frond; Bahia de Los Angeles, Gulf Baja California, Dawson 1335, Apr. 11, 1946 × ca. 1/2

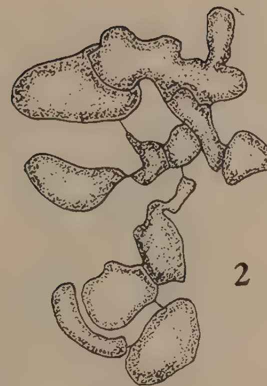
Fig. 2. Habit of an antheridial plant having typical shape; Ensenada Bocochibampo, Sonora, Dawson 455, Feb. 12, 1946 × ca. 2/3

Plate I.

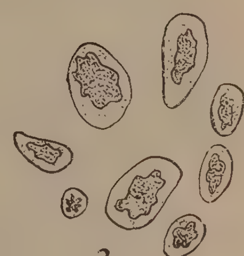




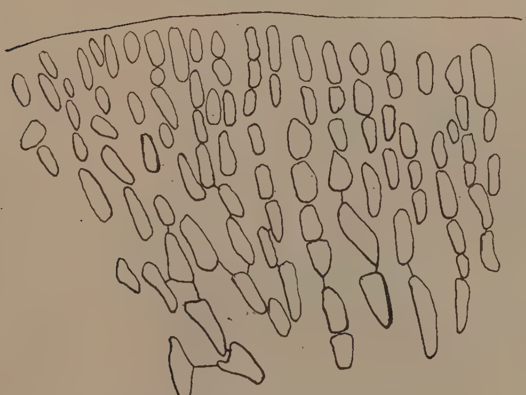
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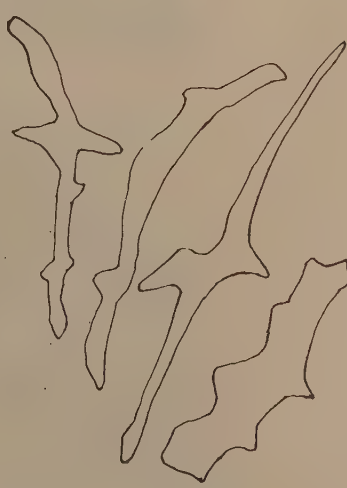
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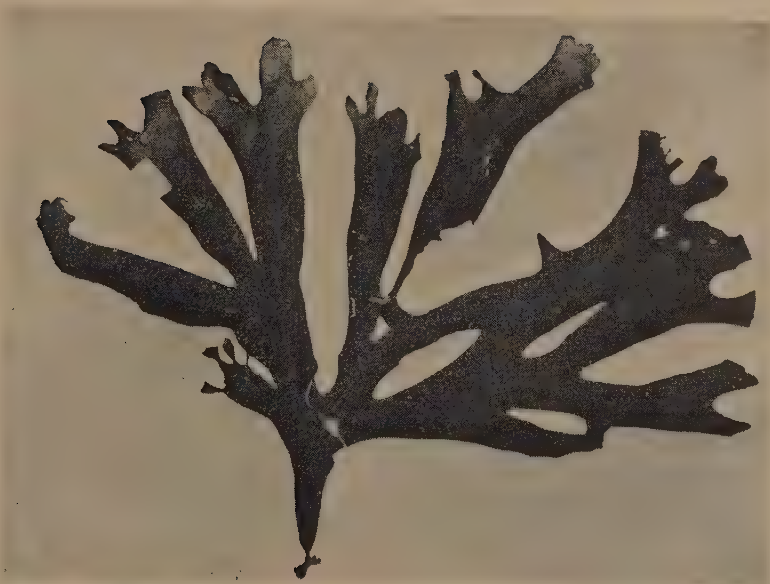
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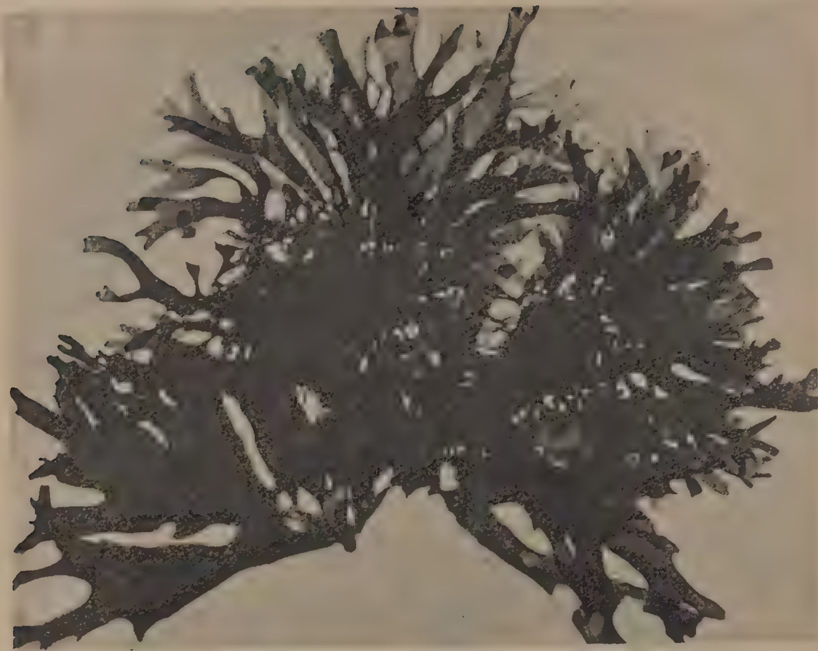
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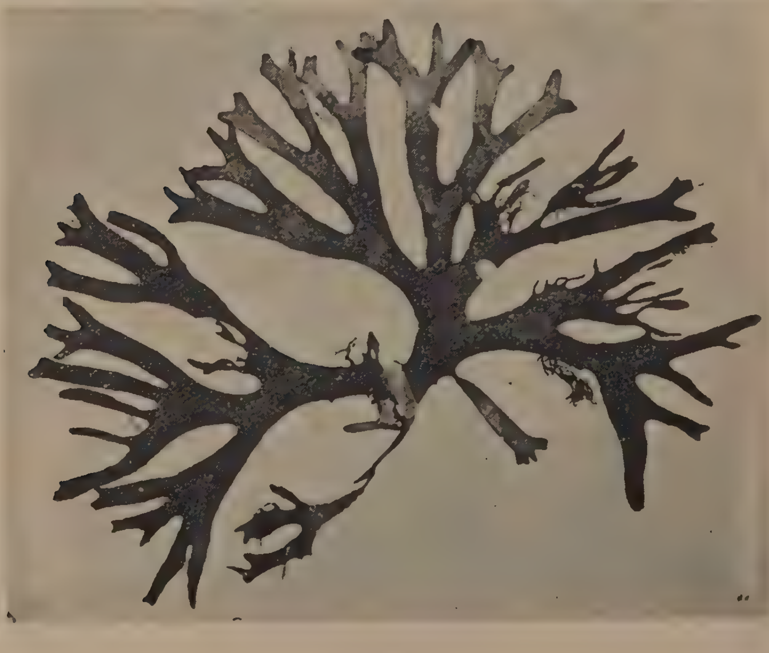
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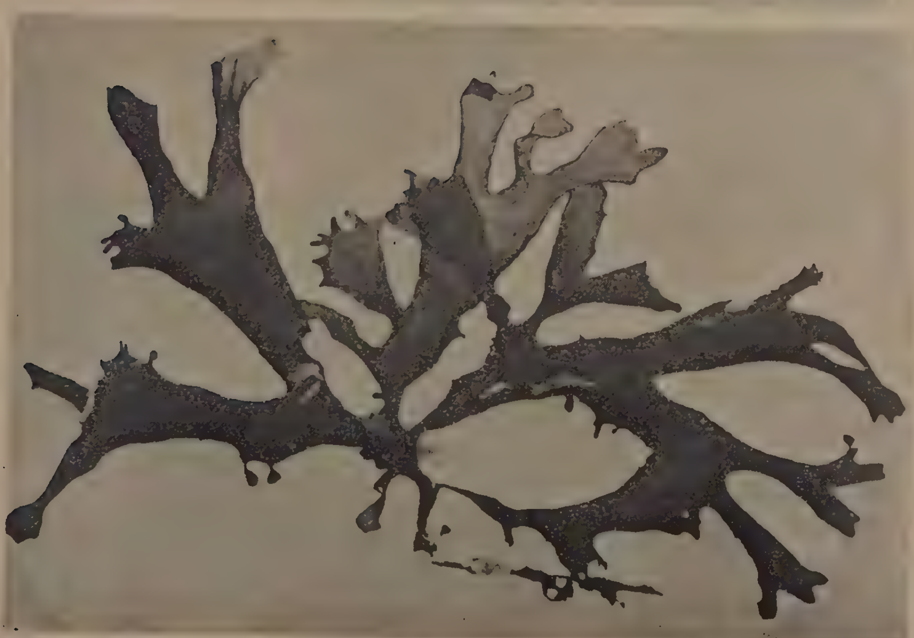
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ON THE MECHANISM OF THE APPEARANCE OF THE SCALE STRUCTURE

III. On the Regeneration of the Scales of the Crucian Carp, *Carassius carassius* (*L.*) when They are reared with the Different Food

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Introduction

Heretofore, all questions into the circumstance of the scale structure have dealt with the idea that the intervals between circuli is controlled by the growth of fish or the quality of food. In his latest work, R. Ichikawa (1953) stated that the absorption of the scale occurs under conditions of mal-nutrition. His opinion is based on histological observations on four individuals of the carp, *Cyprinus carpio*, reared under the condition of starvation during nine or ten months. The present author undertook to examine the relation of nutrition to the growth of scale by the regeneration of scale under the conditions of difference in food. It is the author's opinion that regeneration was not always affected by the nutrition. Furthermore, so far as the present material is concerned the absorption of the bony layer under starvation conditions was not recognized at all.

Observation

Several Crucian carp, *Carassius carassius* (*L.*) two years old, ranging from 2.4 to 4.1 cm in body length were narcotized with urethan, and their right three scales on a scale row just above the lateral line at the posterior part of the foot of a perpendicular from the anterior end of the dorsal fin to the lateral line were removed. Then, they were placed into three normal fresh water tanks, and were fed respectively with crumbs, *Limnodrilus* and non-food during about 40 days in the open at the Institute of the Hokkaido University at Sapporo. The specimens from each tank were examined occasionally. The degree of nourishment was shown by the relation of the body length to the body depth or the body breadth. The progress of regeneration was deduced by the degree of development of the scale structure, additionally, the regenerated scale was sectioned by the paraffin method for histological examination.

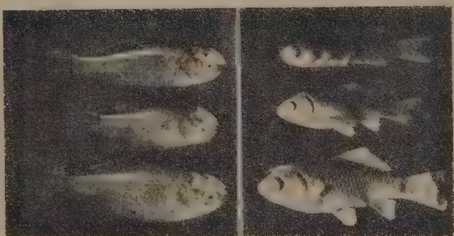


Fig. 1. Specimens from each group at three weeks (June 3rd, 1953) and on the 41st day (June 23rd, '53) after the operation. The former (left) shows the slight difference of the fatness and the complete regeneration of scales, and the difference of the fatness in the latter (right) is clear ; top to bottom, a non-food-, a crumbs- and a *Limnodrilus*-group fish.



Fig. 2. The fibrous layer of the regenerated scale; that of the good-nutrition fish is thicker than that in the mal-nutrition (top).

Within three weeks after the operation, the scales of all fishes were so regenerated that the scar was not apparently recognizable. A slight difference in fatness appeared between the groups (Fig. 1, Table. 1), but the structure of the regenerated scales in three groups was nearly the same; only three or five circuli appear in all the regenerated scales at their anterior part, but the growth of the fibrous layer in the good-nutrition group was somewhat better than in the mal-nutrition group (Fig. 2).

The ratio of body depth to body length was the largest in the *Limnodrilus*-group and smallest in the non-food group. The emaciation in the non-food group resulted from the fact that the body length is almost not affected while the body depth became less. On the other hand, the scales did not shrink, accordingly, the scales overlapped one another in greater degree in the body-depth-axis than in the body-length-axis (Figs. 4, 5).



Fig. 3. Regenerated scale on the 41st day after the operation from a non-food-and a *Limnodrilus*-group-fish, showing the former (left) to be rather clearer than the latter (right) in scale structure.

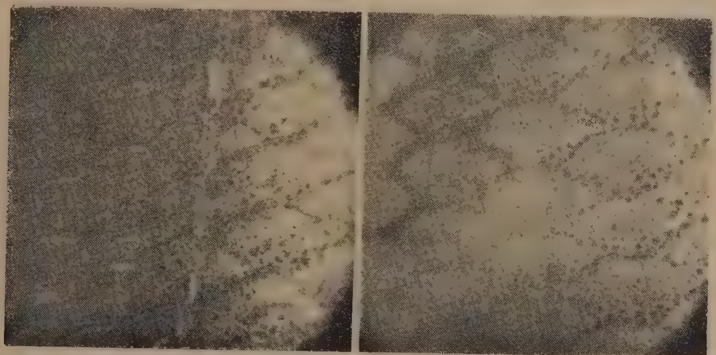


Fig. 4. Skin of the mal- (left) and the good-nutrition fish (right), showing the stronger overlapping of scales of the mal-nutrition as compared with that of the good-nutrition-fish.

The difference of fatness in each group gradually diverged rapidly after three weeks, and by about a month it attained the maximum (Tab. 1, Fig. 1). The emaciation of the non-food group did not increase any more until the death on the fortieth day after the operation. At the last the regeneration of scales presented individual differences as a matter of course, but it is interesting that such structures as the radii and circuli of some regenerated scales in the non-food group were developed more surely in general than those of other groups (Compare two scales of Fig. 3).

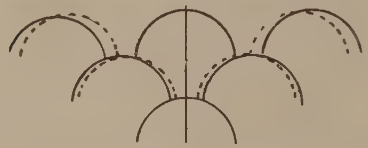


Fig. 5. A diagrammatic figure showing the transfer of scales caused by the fatness of fish.

Table 1. Measurements of specimens in three groups. The emaciation in the non-food group and the growth in the other groups attains maximum in about one month after the operation.

	Date started	Date examined								
	May 12, '53	Jun. 3, '53(3 weeks)			Jun. 13, '53(a month)			Jun. 23, '53(41 days)		
	Body length (cm)	Body length	Body depth (to body length)	Body breadth (to body length)	Body length	Body depth (to body length)	Body breadth (to body length)	Body length	Body depth (to body length)	Body breadth (to body length)
Non-food group	3.60	3.54	1.10 (0.310)	0.51 (0.144)						
	3.20				3.18	0.88 (0.277)	0.51 (0.160)			
	3.30				3.30	0.90 (0.272)	0.54 (0.164)			
	2.40							2.38	0.66 (0.279)	0.39 (0.164)
	2.60							2.60	0.71 (0.273)	0.42 (0.162)
Crumbs-group	2.70	2.85	0.97 (0.340)	0.55 (0.193)						
	2.70				3.10	1.20 (0.387)	0.61 (0.197)			
	3.00							4.24	1.64 (0.387)	0.82 (0.193)
Limnodrilus-group	3.85	3.95	1.41 (1.357)	0.77 (0.195)						
	4.00				4.10	1.59 (0.388)	0.81 (0.198)			
	3.10							3.31	1.28 (0.387)	0.66 (0.199)

Conclusion

The author reported in the previous paper that the outline of scale is regenerated during a short period (Saito, S. & J. Yamada, 1953). In the present experiment there was found also a scale which in size and form was like the removed one within three weeks. However, in this regenerated scale, the upper bony layer which builds the scale

structure is limited only at the peripheral thin part of the lower fibrous layer regenerated completely. This fact shows that the fibrous layer has a close connection with the whole inside of the scale sac while the bony layer has connection with only its periphery. The providing of good-nutrition results in the high growth of the fish, and the growth of the body must be surely accompanied with the growth of the scale sac, hence it is presumable that the growth of the fibrous plate of the scale is influenced by the nutrition. The present result accords with this presumption in respect to the fibrous plate, while the constitution of the bony layer is seen to be independent of the nutrition. It is unreasonable to imagine that a simple mechanical cause such as the destruction of tissue of the scale sac by the removing of the scale has any effects on the regeneration during so long a period as 41 days.

Now, the author is beset by misgivings that the mechanism of the appearance of scale structure may not be directly connected with nutrition.

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ON THE FRESH WATER CATFISH, *PARASILURUS ASOTUS* (LINNAEUS) FROM HOKKAIDO

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The fresh water catfish, *Parasilurus asotus* (*LINNAEUS*), from Hokkaido was reported by S. Sato and K. Kobayashi (1954) on specimens collected from the ponds of Goryokaku-Park and from the Matsukura River of Hakodate City.[1] On the other hand, D. S. Jordan and H. W. Fowler (1903), D. S. Jordan, S. Tanaka and J. O. Snyder (1913), T. Mori (1934, 1936) and S. Tanaka (1928, 1947) have vaguely stated "Japan" or similar words[2] as the distribution area. From their descriptions it is possible to presume that their expressions have the meaning of "Japan excepting Hokkaido". Moreover, D. Miyadi (1940), Y. Okada and M. Nakamura (1948), Y. Okada and K. Matsubara (1938) and S. Tanaka (1952) plainly considered Hokkaido as outside the area of distribution.

From the above, one would not only believe that the fresh water catfish does not inhabit Hokkaido with the exception of a very small area of the most south end but also one would be encouraged to believe that its distribution into the south end of Hokkaido may be artificial. The present writers find now that this species inhabits naturally a part of Hokkaido, an area north of Asahigawa City far from the

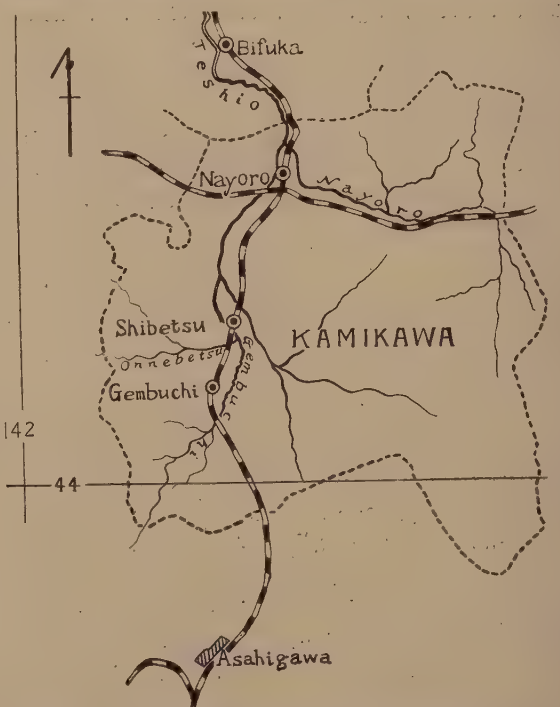


Fig. 1. Region where specimens were collected

1) They cited Shimamatsu in the vicinity of Sapporo as the locality.

2) "Japan proper" by T. Mori, "Inland of Japan" by S. Tanaka

south-most part, and it may possibly live universally in Hokkaido.

The specimens described in this paper were collected from the Gembuchi and Otonashi Rivers and several ponds in the watershed of the above two rivers in Kamikawa-Gun, Teshio Province, at about north latitude 44° (Fig. 1). They inhabit together with *Carassius carassius L.* in the turbid water in the peat-bog. It is assumed that they are not scarce for the angling for them is continuously carried on by local persons.

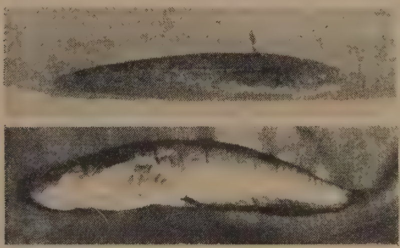


Fig. 2. Specimens collected by K. Hasekura (top) and K. Sato from the Otonashi River

The measurements of the specimens are as follows:

Locality	Date collected	Collector	Body length(cm)
Otonashi River	May 11, '54	Kakuo Hasekura	12.70
〃	June 2, '54	Kanji Sato	18.50
Old waterway of the Gembuchi River	June 3, '54	Kimiye Miyake	35.00
〃	June 13, '54	Kaname Yokoi	12.00

One specimen collected by the junior writer by angling from an old waterway of the Gembuchi River on the 13th of June is different from the others in the number of barbels and the lateral line. The barbels are six : two very long maxillaries and four short mentals, and the lateral line is white and extraordinarily clear. It is probable that this fish is a young one, but the writers are rearing specimen for the purpose of observation on the fate of barbels.

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STUDIES ON THE NUTRITIVE VALUE OF THE MEAT OF SEA CUCUMBER (*STICHOPUS JAPONICUS* SELENKA) *

I. General Introduction and Explanation of Plan of Investigations

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Faculty of Fisheries, Hokkaido University

It has been reported that more than one hundred species of sea cucumbers (Holothuroidea) inhabit the waters near Japan, most of them living in the southern areas. But the edible species utilized commercially as either raw or dried materials are restricted to about 20 species. Of these species, *Stichopus nigripunctatus* ("Okiko", in Japanese, in Miyagi Prefecture and "Kurohoshi-Namako" in Hokuriku District), *Cucumaria japonicus* ("Fujiko", in Japanese) and *Stichopus japonicus* ("Namako" in Japanese) are common, and among them the last one is the most important because of the large amount of catch, being highly regarded as commercial goods. *Stichopus japonicus* has different Japanese names according to the localities, e. g., "Akako", "Kuroko", "Torako", "Tawarago" and so on.

The dried goods, after boiling, of the sea cucumber, *Stichopus japonicus* produced in Japan has been one of the important exportations to China from old times.

As the holothurians which have, or have not, papillae on the surface of the body wall according to the species, the dried materials are also classified into two kinds by the presence or absence of papillae. In China the dried sea cucumber having papillae is called "Tsusan", while those without papillae is called "Kosan". In the commercial market the former is called "Haisan" (dried black sea cucumber) and the latter "Paisan" (dried white sea cucumber). In Honshu of Japan the dried sea cucumber for the market is manufactured using only the species having papillae, but a small quantity is manufactured from the species without papillae in the Bonin and Loochoo Islands. The materials of dried goods manufactured in Hokkaido, Honshu, Shikoku and Kyushu are almost entirely confined to a single species having papillae, *Stichopus japonicus*. It is an interesting fact that in sea cucumber the number of papillae decreases and the projection of papillae becomes blunt in the various species found from north to south, the papillae being replaced by mere swollen knobs in the materials from south eastern Kyushu.

The quality of the dried merchandise of sea cucumber is largely graded by the size, i. e., by height and sharpness of the papillae. The materials with conspicuous papillae are regarded as high class. In this respect the dried merchandise manufactured

* This "Studies on the nutritive value of the meat of sea cucumber" is the first part of "Chemical studies on the meat of sea cucumber (*Stichopus japonicus* SELENKA)".

from *Stichopus japonicus* in Hokkaido has the highest quality, while that from southern areas is lower. Both *Stichopus nigripunctatus* in Miyagi Prefecture and *Cucumaria japonicus* in Hokkaido have no papillae, so that their marketable value is low, and the sea cucumber in Amami-Ohshima, Bonin Islands, Loochoo Islands and South Sea Islands, though there are many edible forms, are also considered low in quality due to absence of papillae.

The raw meat of the body wall of sea cucumbers is utilized for food in Japan by cutting and vinegaring; salted internal organs (called "Konowata" in Japanese) are also used. Drinkers are reportedly very fond of both.

Before World War II the production of dried sea cucumber merchandise was amounted to 1000000 Yen a year, but it has been suspended since the War because of the stopping of trading between Japan and China.

Recently the dried sea cucumber has again been regarded with keen interest as a possible important export commodity.

The author has recently succeeded in preparing canned sea cucumber. The canned food has various advantages for use in various sorts of cooking, and it is expected to be suitable to the taste of the Chinese.

It has been said that there are many differences between the meat of sea cucumber and that of fish, but the chemical properties of the meat of the former are still unknown in detail. Accordingly various difficulties remain in canning process. There have been published a few reports on the chemical properties of the meat of sea cucumber, *Stichopus japonicus*. Sekine[1] and Fränkel & Jellinek[2] have studied the nitrogen distribution of the meat of sea cucumber, and Tsujimoto[3] on the fat. Igarashi[4] has analysed the dried market sea cucumber, reporting the general chemical components.

Some of the biological reports will be referred to here, because the chemical properties of the meat are greatly influenced by the conditions of life of animals, e. g., breeding and hibernation. Mitsukuri[5] and Tokuhisa[6] made observations on the life history of sea cucumber and Inaba[7] has tried artificial fertilization. Feeding and breeding habits were investigated by Kinoshita[8][9] in Hokkaido.

In a series of investigations on the chemistry of the meat of sea cucumber, the present author as the project leader has attempted to do research in the order of (1) nutritive value, (2) post-mortem changes and (3) properties of the protein. The investigations under the present main title, take the form of "chemical studies on the meat of sea cucumber, *Stichopus japonicus*," mainly dealing with its nutritive value. It is expected that the various methods of manufacture of sea cucumber will be more developed when the chemical and physical properties of the meat are clarified in detail.

Before going further, it will be necessary to touch on the body system of a useful sea cucumber, *Stichopus japonicus*. Originally the body system of the

holothurians is arranged in radial symmetry as in other echinoderms, e. g., sea urchins, sea stars and so on. However, in holothurians the animals are crawling on and burrowing into the sand of the sea bottom with their bodies kept horizontal. Because of the position of the body and habit of movement, the underside of the body facing toward the sea bottom is somewhat differentiated in structure. Therefore, for practical convenience in the present report, the side of the body facing upward is called the dorsal side of the body and the side facing downward is called the ventral side.

According to the histological observations,* so-called meat, i. e., edible part, of sea cucumber mainly consists of loose connective tissue together with the thin surface skin (epidermis) and inner membrane (epidermis) facing to the body cavity (coelom). The muscular tissue is very rare. There are only five radial bands of muscle and thin muscular layer along the inner layer of the body wall. That is to say, the edible part which is usually called meat of sea cucumber is histologically not composed of muscular tissue, but mainly of connective tissue. Such tissue consists of collagen fibers forming a network together with a small quantity of muscular tissue. In the present investigations a large part of the connective tissue together with a small part of the muscular tissue are treated as the meat samples for chemical studies.

The flesh meat of *Stichopus japonicus* contains a large amount of water, the water content being about 90%. When the body of *Stichopus* is dried after boiling, the size is decreased by 1/5 or 3/10, and the weight is decreased by about 1/20.

In the following articles numbered II, III, IV, … the plan is to report "Studies on the nutritive value of the meat of sea cucumber, *Stichopus japonicus*," the results of estimation of the chemical components, digestibility, the kinds and contents of amino acids composing meat protein and chemical components of meat extractive matter.

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* This histological observation has been aided by Mr. Eijiro Niiyama

STUDIES ON THE NUTRITIVE VALUE OF THE MEAT OF SEA CUCUMBER (*STICHOPUS JAPONICUS* SELENKA)

II. Seasonal Changes of Chemical Components of the Meat of *Stichopus japonicus*

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Faculty of Fisheries, Hokkaido University

It is important to take into consideration the variation of chemical components of the sea cucumber in preparing various forms of food from sea cucumber.

The chemical components of animal bodies varies clearly with the development of the gonads and conditions of feeding. The present authors have analysed monthly the chemical components of bodies of *Stichopus japonicus* which are caught in the sea near Hakodate.

Experimental Part

(1) Sample

As samples many individuals of *Stichopus japonicus* were employed, of a length of about 15 cm and as nearly alike as possible. Because it is impossible biologically to judge the age of sea cucumber, it follows that there was no certainty that sea cucumbers of the same age were used. The length of sea cucumbers caught from January to March was about 10 cm, since sea cucumbers of that season are very small owing to the hibernation. The difference of male and female also cannot be judged except in the spawning season of July and August[1]. The samples used in these experiments were without distinction of sex. The samples of sea cucumbers which were caught in the early part every month were analysed.

(2) Method of experiment

The sample of living sea cucumber was split on ventral side, then part of belly cavity wall and part attached to surface skin were cut off as shown in Fig. 1.

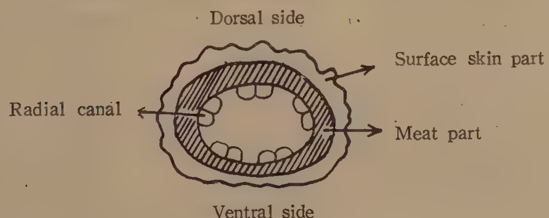


Fig. 1. Sample used

The part of meat was taken and crushed with a sharp knife into very small pieces; the amounts of water-content, ash, total nitrogen, protein-nitrogen and crude fat were estimated by the usual methods.

The amount of protein-nitrogen was estimated by Kjeldahl's method using precipitated protein substance with

10% trichloracetic acid solution. The crude fat was estimated by using Soxhlet's extractor. The samples of every month were the crushed meat prepared from several bodies of sea cucumber of the same size.

(3) Experimental results

Experimental results obtained are shown in Table 1, 2 and Fig. 2

Table 1. Seasonal change of proximate composition of sea cucumber meat (Per cent in raw material)

Experimental articles / Date	Water content	Ash	Total-N	Protein-N	Protein-N / Total-N	Crude fat
1953 May 19	88.85	2.28	1.35	0.64	47.4	0.88
June 9	89.10	1.12	1.38	0.47	34.1	1.14
July 7	91.19	0.82	1.15	0.44	40.0	0.56
Aug. 15	90.20	1.37	1.23	0.40	32.5	0.76
Sept. 16	88.50	1.93	1.30	0.70	53.8	0.98
Oct. 16	87.76	1.89	1.36	0.83	61.0	1.01
Nov. 4	88.86	2.13	1.15	0.70	60.8	1.22
Dec. 4	87.42	2.16	1.04	0.67	64 4	0.80
1954 Jan. 5	84.89	2.73	0.97	0.50	51.5	1.44
Feb. 8	90.01	1.32	1.05	0.57	54.3	2.32
Mar. 12	90.80	0.20	0.71	0.35	49.3	0.60
April 7	91.30	1.35	1.03	0.57	55.3	0.44
Average	89.08	1.61	1.14	0.57	50.4	1.01

The average calorie value during one year of 100 g of sea cucumber is 38. 7 cal.

Table 2. Seasonal change of proximate composition of sea cucumber meat (Per cent in dried material)

Experimental articles / Date	Ash	Total-N	Protein-N	Crude fat
1953 May 19	20.5	12.09	5.74	7.88
June 9	10.3	12.67	4.30	10.45
July 7	9.3	13.04	4.99	6.70
Aug. 15	14.0	12.52	4.08	7.76
Sept. 16	16.8	11.26	6.09	8.50
Oct. 16	15.0	11.12	6.78	8.25
Nov. 4	19.1	10.32	6.28	10.90
Dec. 4	17.2	8.26	5.33	6.36
1954 Jan. 5	18.1	6.42	3.31	9.52
Feb. 8	13.2	10.49	5.69	23.20
Mar. 12	2.2	7.73	3.79	6.52
April 7	15.5	11.82	6.54	5.06
Average	14.3	10.64	5.16	9.26

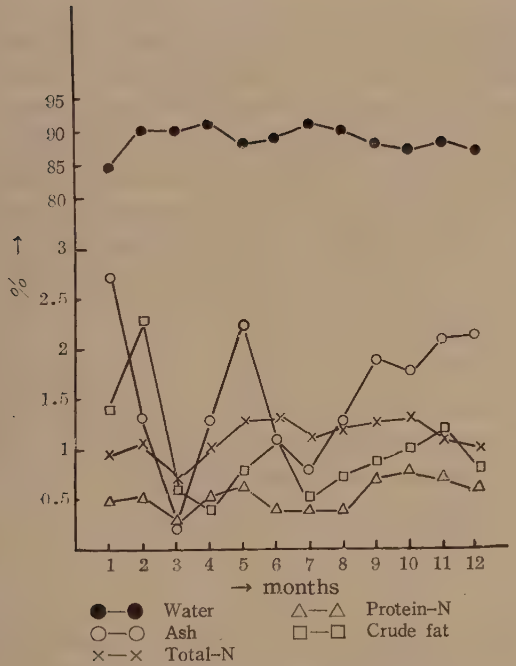


Fig. 2. Seasonal change of proximate composition of sea cucumber meat (Per cent in raw material)

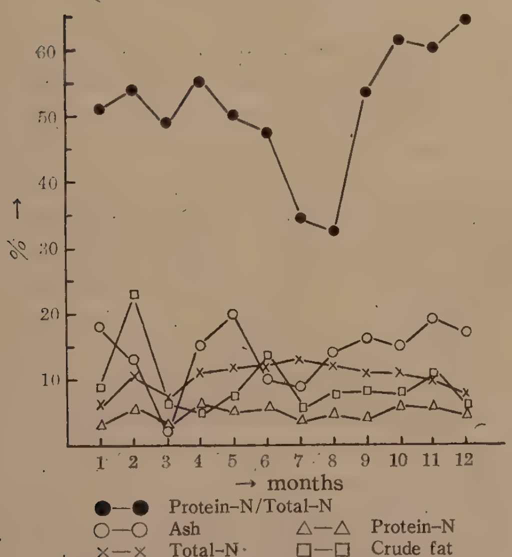


Fig. 3. Seasonal change of proximate composition of sea cucumber meat (Per cent in dried material)

As seen in Fig. 2, the amount of water content varied from the minimum of 85% in January to the maximum of 91% in July. That is to say, the amount of water content which showed the maximum value in July, decreased to a minimum in January of the next year. From February the amount of water content increased again gradually, but there was no remarkable variation between February and May. The amount of fat content varied from the minimum of 0.56% in July to the maximum of 2.3 % in February. Amounts of water content and fat content were relatively just the opposite.

In fatty fish meat, e. g., sardine[2)3)4)] and herring[5,6)], there can be seen remarkable variation of the amount of fat content in relation to the growth of the gonads. In the meat of sea cucumber, there is also a variation of the amount of fat content in relation to the growth of gonads, but the amount of fat content is not very large in comparison to the other fish. The amount of fat content increased gradually from September to January, and then the amount decreased from February to May. The amounts of crude and pure proteins also showed nearly the same variation. In the variation of the amount of ash content, it showed the minimum value of about 1% in July and August, while in other months the amount of the

ash content varied between 2 and 3%.

As seen in Fig. 3 showing the percentages of each chemical component of the dried matter, the variation of those percentages of fat, ash and pure protein was the same as the variation of the percentages of the original matter. The amount of the crude protein showed the minimum value in January, then it increased slowly to exhibit the maximum value from June to August, followed by a gradual decrease from September. Therefore, the percentage of protein nitrogen in relation to total nitrogen showed the minimum value from June to August, and it increased gradually from September to December, but it decreased slowly with the falling of the water temperature.

Discussion

As stated above each component has generally some variation from July to August and from January to February as the zeniths. Considering from the habit and the food of sea cucumbers, as studied by Kinoshita and Shibuya[7] of Hokkaido Fisheries Station, the breeding season in Hokkaido is from early August to early September in the district of Okushiri Island, from the end part of June to early August in the district of Mashike, from the end of June to the end of July in Yagishiri Island, from the end of July to the end of August in the district of Wakkanai, from the end of June to the end of August in the district of Muroran, and from early in July to the end of August in the district of Shikabe, respectively. General speaking, the breeding of sea cucumber is done in water of 13°～20°C from July to August.

As to the habit of sea cucumbers, Mitsukuri[8] has found definitely that sea cucumbers estivate for about two weeks in the middle of July in Kanazawa Bay, Kanagawa Prefecture. He found that during that estivation they do not take food, and the digestive organs contract to line shape.

According to Kinoshita and Tanaka[9], the kind and the quantity of the contents in the stomachs of sea cucumbers about Hokkaido are quite the same from early May to mid-September, and there may not be any estivation. According to Kinoshita and Shibuya[7], sea cucumbers of Hokkaido may enter a period of dormancy something like estivation after the middle of September; during that period they hide in caves. They creep out temporarily in about January of the following year as "winter sea cucumber", but again hide in caves. Then with increase of water temperature they creep out for the summer after the end of April. The contents of the stomach of the sea cucumbers were confirmed to be 60 kinds of diatoms, 14 kinds of such abiogenesis as plankton and frequently larvae of sardine and other fish or algae.

Considering comparatively from studies on the habits and feeding of sea cucumbers and the results of the present authors' experiments, the fact that the amounts of fat, crude protein and ash in the meat of sea cucumber are at a minimum of

comparatively small quantity in from July to August, may be due to the consumption thereof in the course of breeding. After the breeding in September, each component lost will be restored by active taking of food to prepare for hibernation. Consequently each component of the meat increased, and the amount of water content in the meat will decrease relatively.

During the dormancy in the period from mid-September to December the components accumulated, but especially fat and protein will be consumed again. They creep out temporarily in about January to take supplementary food. Sea cucumbers which creep out temporarily in this season are customarily called "winter sea cucumber".

From March to April, the amounts of fat and protein in the meat may test out small owing to the consumption of the components in the body during the period from February to early April. From the end of April to June, the amounts of fat and protein will increase gradually on account of active taking of food following permanent creeping out from their caves to prepare for breeding.

Summary

The amounts of the chemical components in the meat of sea cucumber (*Stichopus japonicus*) vary from July to August and in January. The variation which occurs from July to August is due to the breeding, and the variation in January is due to the taking of food as a habit.

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STUDIES ON THE NUTRITIVE VALUE OF THE MEAT OF SEA CUCUMBER (*STICHOPUS JAPONICUS* SELENKA)

III. A Comparison of the Chemical Components of the Meat of Sea Cucumber with the Meat of Other Marine Animals

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The so-colled meat (edible part) of sea cucumber consists mainly of connective tissue, as above stated, on the other hand, the edible part of aquatic vertebrates (including fish) and molluscs consists of muscular tissue. Hence there may be remarkable differences between them.

Estimations were made of the chemical components of food for human comsumption derived from such creatures, from the sea cucumber (caught in January and August) and aquatic mammal (whale meat), fish meat (red flesh fish and white flesh fish), and molluscs (Cephalopoda, Gastropoda). The results are collected in Table 1.

Table 1. Comparative results of evaluations of proximate composition of the meat of sea cucumber and other aquatic animals[1a)1b)]

	Per cent in raw material				Calorie / 100 gm meat	Per cent in dry-matter		
	Water content	Crude protein	Crude fat	Ash		Crude protein	Crude fat	Ash
Whale (red meat)	70.18	20.95	7.62	1.25	156	70.25	25.55	4.19
Dolphin	72.80	16.81	8.13	3.25	144	61.80	29.89	11.95
Herring	74.64	14.55	9.03	1.78	143	57.37	35.61	7.02
Cod	82.30	16.85	0.48	1.23	73	95.20	2.71	6.95
Ear-shell	73.00	24.56	0.44	1.98	104	90.96	1.63	7.33
Octopus	77.00	17.07	4.57	1.42	112	74.22	19.87	6.17
Clam	78.75	11.27	1.62	1.47	61	53.08	7.62	6.92
Oyster	80.38	13.31	1.51	1.96	68	67.84	7.69	9.99
Sea cucumber (Jan.)	84.89	6.50	1.44	2.73	40	43.02	9.53	15.68
Sea cucumber (Aug.)	90.20	7.67	0.76	1.37	38	78.26	7.76	13.98

The chemical components of the meat of sea cucumber differ remarkably from those of other aquatic animal meats in respect to the fact that the former has a larger quantity of water and smaller quantity of crude protein and fat than the latter.

The fact that sea cucumber has larger quantity of ash may be because the meat of sea cucumber can not be separated from the spicule which corresponds to the bone of fish.

Aquatic vertebrates such as fish have a large quantity of fat in their muscular tissue (except cod or flat fish) and the amount of fat content varies seasonally having relation to the conditions of sexual glands.

Sea cucumber has glycogen in the meat as a reserve in addition to fat.

According to the results of experiments of the present authors, the quantities of glycogen estimated for sea cucumber, which is soon to enter hibernation with falling of water temperature in about December, or which is soon to begin breeding in about June, are 0.799% in original matter (5.28% in the dried matter) or 0.881% (8.09%) respectively. Such estimation have been made previously. According to evaluations of the amounts of glycogen in various sorts of fish meat, shark contains glycogen of 0.018% (as glucose)[2], carp 0.29%[2], bonito (3 hours after the death) 0.013%,[3] and *Gadus aeglefinus* (a kind of cods) 0.4~0.6%[4]. The amount of glycogen content in the meat of sea cucumber is larger than that in the meat of fish.

However, the amount of glycogen content in oyster meat varies seasonally, as much as 14.6~21.6% in from November to March of the next year, 8~9% in May, 6% in June (all the glycogen content is for the dried matter respectively)[5].

The glycogen contents in the meat of sea cucumber is smaller than the maximum quantity contained in oyster meat, but almost the same as the minimum contents.

The amount of fat contents in the meat of sea cucumber is almost the same in oyster and clam meat.

Generally speaking, the amount of chemical components of the meat of sea cucumber is smaller in respect to the quantities of crude protein content and fat content, but is larger in the quantity of water content than other aquatic vertebrates. Therefore the calorie of the meat of sea cucumber is nutritively inferior to the meat of aquatic vertebrates and molluscs.

Summary

The amount of water content in the meat of sea cucumber is about 90% being larger than that of fish meat. However, the amounts of protein and fat are very small in absolute values. That is to say, the nutritive value of the meat of sea cucumber is inferior to the meat of aquatic vertebrates and molluscs.

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STUDIES ON THE NUTRITIVE VALUE OF THE MEAT OF SEA CUCUMBER (*STICHOPUS JAPONICUS* SELENKA)

IV. Digestibility of Meat of Sea Cucumber

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From olden times, sea cucumber (*Stichopus japonicus*) has been eaten as a vinegared food with relish in Japan. When the raw meat of sea cucumber is vinegared, the meat protein is coagulated causing the meat to become hard. It has been a popular impression that the vinegared meat of sea cucumber is indigestible.

The authors have tried to estimate the digestibility of raw meat, vinegared meat, boiled and dried meat, canned meat of sea cucumber, respectively, with pepsin and have compared the digestibility of them. At the same time the authors have also tried to estimate the digestibility of raw flat fish and Atka mackerel meat for the sake of comparison and contrast.

There are methods of testing digestibility which use animal bodies, and also artificial chemical tests using pepsin. There are also many possible methods for use in the artificial chemical test. One of them is a method of estimating the digestibility from the amount of total nitrogen in the sample and nitrogen in the undigested residue of the sample. There are available for example Wedmeyer's method,[1] Wagner's method[2] (reformed Wedmeyer's method), Ōshima and Itaya's method,[3] and reformed Ōshima and Itaya's method.[4] The other method is based upon estimates of the amount of total nitrogen in the sample and nitrogen in the filtrate of digested sample. For example the Tomiyama and Ishikawa method,[5] or the Kimura method.[6] Those methods are almost equal in their value.

Experimental Part

(1) Sample

As samples, (1) raw meat, (2) vinegared meat, (3) canned meat, (4) boiled and dried meat were employed. As contrasting sample, raw flat fish meat and raw Atka mackerel meat were also employed.

Skin and viscera were removed from two raw fresh sea cucumber bodies (300 g) and the part of so-called meat was crushed. Twenty grams of the crushed meat was employed as the sample.

Vinegared meat of sea cucumber was made from the pickling of four bodies (425 g) in 3% acetic acid solution for a week. The vinegared meat was prepared similarly as the raw meat.

Canned meat which was manufactured by Tanikawa's patented method[7] was

employed in the same way as the raw meat.

Boiled and dried meat was made from the boiling of 17 raw bodies of sea cucumber (2300 g), which had been viscerated, for 15 minutes. Material was then dried in the sun for 3 days. When the dried bodies are employed as sample, they were soaked in water and then were treated similarly to the manner in which the raw meat was treated.

Raw flat fish and Atka mackerel meat were skinned and boned and then 20 g of treated meat of each fish was employed as samples.

(2) Experimental method

The amounts of water content and protein nitrogen of each sample were estimated. Then 20 g of each sample was put into an Erlenmeyer's flask of 200 cc volume, and then 100 cc distiled water and 1 g of pepsin of "Merck" were poured into the flask and mixed homogeneously to dissolve pepsin completely. Next, 100 cc of N/5 HCl solution was also added to the material in the flask and the flask was left at 37°~38°C for 44 hours. After digestion of the samples, the amount of protein nitrogen in the undigested residue of the samples was estimated.

The digestive effect of the employed pepsin was estimated by the dilution and sedimentation method of Fuld-Lerison.[8)] That is to say, the digestive effect was estimated by ascertaining what volume in cc. of 1% edestin solution can be digested by 10 cc of the definite diluted solution of pepsin at room temperature for 30 minutes. The result obtained for the digestive effect of the pepsin was as follows:

$$P^{20}_{30} = 64 \text{ Units}$$

The digestibility of the samples was calculated by the following equation.

$$\text{Digestibility} = \frac{\begin{pmatrix}\text{The amount of}\\ \text{protein-N}\\ \text{in the sample}\end{pmatrix} - \left\{\begin{pmatrix}\text{The amount of}\\ \text{protein-N in the}\\ \text{undigested residue}\end{pmatrix} - \begin{pmatrix}\text{Nitrogen in the}\\ \text{pepsin after the}\\ \text{digestion}\end{pmatrix}\right\}}{\text{The amount of protein-N in the sample}} \times 100\ (\%)$$

Note: (i) The amount of protein-N was estimated after removing protein by Stutzer's reagent.

(ii) The amount of pepsin-nitrogen was estimated under the same condition of meat digestion as follows: After 100 cc of N/5 HCl and 100 cc of dist. water were added to 1 g of pepsin in a flask, and the mixture was left at 37°~38°C for 44 hours, the amount of protein-N was estimated by removing of protein in the flask by Stutzer's reagent.

(iii) The amount of the total nitrogen in 1 g of original pepsin was estimated by Kjeldahl's method. It was 22.8 mg. The amount of nitrogen in pepsin after the digestion was 5.78 mg by the above described method.

(3) Experimental results

The results obtained are shown as Table 1.

Table 1. Comparative results of digestibility with variously treated sea cucumber meat

Sample	In Sample		Protein-N in residue after digestion (mg.)	Protein-N in pepsin after digestion (mg.)	Digestibility (%)
	Water content (%)	Protein-N (mg.)			
Fresh sea cucumber meat	87.68	206	83	5.78	62.5
Sea cucnmber meat with vinegar	86.45	278	23	5.78	86.5
Canned sea cucumber meat	77.47	358	72	5.78	81.4
Dried sea cucumber meat after boiling	67.60	504	76	5.78	85.9
Fresh flat fish	79.57	261	11	5.78	97.9
Fresh Atka mackerel	78.26	263	13	5.78	97.3

As indicated in Table 1, the digestibility of raw meat of sea cucumber is inferior to the raw flat fish meat or raw Atka mackerel meat. However, when the raw meat is converted into vinegared food, canned food or boiled and dried food, the digestibility of the processed meat became better.

If the meat of sea cucumber is boiled to prepare canned food or dried food, the properties of the protein in the meat change and become decomposable by some enzyme such as pepsin. This fact agrees with the results obtained by the senior author[9] who found that the boiled squid or flat fish meat is more digestible than the raw meat.

It is remarkable that the vinegared meat of sea cucumber is more digestible than has been formerly imagines, since it is known that the protein of meat of sea cucumber is coagulated by vinegar and the meat become hard and uncrisp. This is perhaps due to the fact that the acidified meat of sea cucumber becomes decomposable by an enzyme.

The meat of sea cucumber is rarely eaten as raw food. It is eaten as vinegared food in Japan or as boiled food in China, so there is no fear of indigestion.

From the results of the present experiments it may be concluded that the meat of sea cucumber should be eaten as vinegared food, canned food or boiled food. In a word, the meat of sea cucumber is rather a tasty food than a nutritive food.

Summary

The digestibility of raw meat of sea cucumber, showing a value of about 63%, is inferior to that of fish meat, showing 98%. The digestibility of the meat can be increased by boiling or vinegaring to a degree of 80～86%. That is to say, the meat of sea cucumber is not a very good nutritive food. It is better to treat the meat by boiling, canning or vinegaring.

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鮫肉腐敗の微生物化学的研究

第1報　鮫肉の腐敗に於けるUrease Activity 及び細菌群の消長について

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Studies in the Bacteriological Chemistry of Shark Muscle Spoilage

I. On the changes of urease-activity and bacterial flora during shark muscle spoilage

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Abstract

In the present work, the authors observed the change of urease-activity in infusion of shark muscle and the change in the bacterial flora during its spoilage. As a result it can be summarized as the following:

1) In the beginning the urease-activity increases. In four or five days it reaches to the highest point. After that there is a great production of ammonia and decomposition of urea, while the urease-activity decreases rapidly. On about the twentieth day the urease-activity rises again but decreases immediately there after.

2) The change in the bacterial flora was observed as follows: (A) In the first stage, bacterial groups III, IV and V (grown on medium containing urea) grew very rapidly, and increases to almost the same number as bacterial groups I and II (grown on bouillon agar medium). But following that the growth stops after about fifteen days and their number becomes about 1% of that in groups I and II. In the latter period these grew slightly again. (B) Till about fifteen or twenty days, groups I and II grew logarithmetically. But in the last stage they stopped their growth and even showed some decrease. (C) Bacterial group VI (grown on medium using sole ammonium chloride as nitrogen source) showed a similiar tendency to groups I and II, but its number was a little less than that of groups I and II.

3) From the results of 1) and 2) the following inferences have been drawn: (A) The change in the urease-activity has close relation to the changes in the bacterial flora. (B) In the spoilage of shark muscle, the principal decomposition of urea is caused by bacterial enzyme. (C) The greater part of the bacteria in groups I and II must have been the same as those in group VI.

板鰓類の諸組織器管中に1～2.5%にも及ぶ多量の尿素が存在すると云う事は古くから多くの研究者に依り報告されている。[1,2,3,4] 此の様に他の魚類に比較して尿素含量が特異的に多い板鰓類就中鮫肉等は鮮度低下，腐敗の際は勿論冷蔵保存中に於ても多量の ammonia を発生すると云う事も又多くの研究者に依り報告されている。[3,5,6,7,8,9] 此の多量の ammonia は勿論多量に含有する尿素の分解に依り発生する事は疑う余地の無い所であるが，その発生機構に付ては未だ確たる定説が無い様である。最近清水[9]，高橋[11]等に依り其の原因の大部分は尿素分解細菌に依るもので有ろうと報告されているが，森・小林[2]，Wood[13]等は鮫筋肉及び血液中に urease の存在を報告して居り，其の初期に於ける尿素の分解が自家消化酵素によるものではないかと云う事も否定出来ない事実であろう。いづれにせよ斯の如く多量の尿素を含有する魚類の腐敗には当然尿素分解細菌が大きな役割をなして居るだろうと云う事は想像に難くはない。Wood[13]は鮫肉の変敗を細菌学的に研究し，此の変敗に関係する細菌は1種の海洋性の細菌で，多くは海泥中の細菌に似て居ると報告して居り，又最近木俣[1]等も鮫肉の変敗を細菌学的に研究し尿素分解細菌が鮫肉の ammonia 発生の際の重要な役割をすると云う事が考えられると述べて居る。斯の如き特異的な鮫肉の腐敗を model として生活要因の

変化と細菌相或は細菌の酵素活性の変化との関係を追求する事は興味深い事であり，又板鰓類魚肉の ammonia 発生機構解明の一助ともなし得ると考えられる。著者等は以上の観点から本研究を始め，本報に於ては先ず鮫肉の腐敗進行中に於ける尿素，及び ammonia 量の変化と鮫肉水抽出液中の urease 活性の変化及び細菌群の消長を測定し，若干の結果を得たので報告する。

実　験　I

a）試料及び方法

1953年5月22日函館近海に於て漁獲され鮮度の極めて良好なアブラツノザメ, *Squalus suckleyi* (GIRARD), を可及的細菌汚染の無い様注意して脱皮後，頭部及び骨部，血合肉を除いた全精肉を，煮沸殺菌したチョッパーで2回繰返し肉挽し，殺菌綿栓フラスコに10g及び5gづつ分取し，13°～17°Cに貯蔵し試料とした。後一定日数毎に urea-N，ammonia-N 及び水抽出液の urrease活性を次の様な方法により測定した。

先ず ammona-N は10gの試料を用い通気法[15]により測定した。urea-N の測定には5gの試料を水と共に良く磨砕し，水で3回抽出遠心分離を繰返し全量を 100 ml となし Seitz 細菌濾過器にて濾過し，此の液1mlに urease を作用させて生ずる CO_2 量を Warburg の検圧計を用いて測定し[15] その量から urea-N 量を算出した。尚 ureaseは G. Grübler co. 製のものを用い，反応は38°C, pH5で210分行つた。urease 活性の測定は前記抽出液の細菌濾過器を通さぬ液1mlを用い，3%尿素水溶液を基質とし38°Cで30分及び60分間の反応にて発生するCO_2量を測定し，其の測定値より1mlの試料が1時間に発生するCO_2の μl を算出し，それを以て urease 活性とした。尚本実験に於て ammonia-N と称し測定して居るものは厳密な意味に於ては揮発性塩基—N に相当するものである。

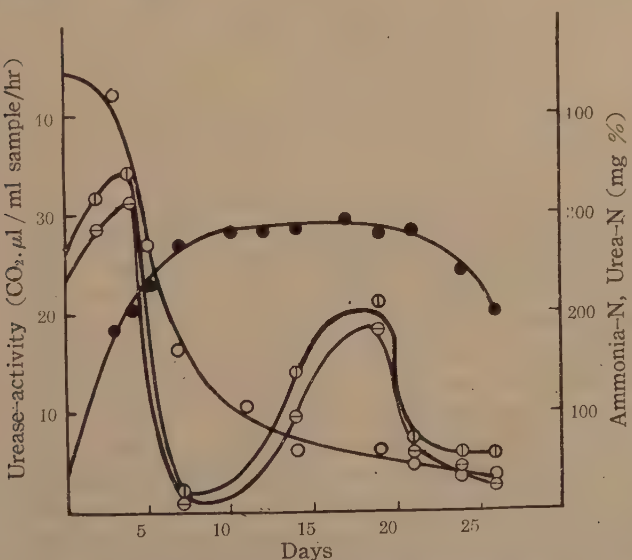


Fig. 1. Changes of urease-actity, ammonia-N (volatile-N) and urea-N in shark muscle during spoilage at 13° to 17°C

⦶ Urease-activity, measured at 30°C for 1 hr.
⊖ 〃 〃 〃 30 min.
● Ammonia-N
○ Urea-N

b）結　果

以上の方法に依り腐敗進行過程に於ける一定日数毎のurea-N及び ammonia-N の増減量及び水抽出液の urease活性を測定した結果をFig. 1 に図示した。即ち初期4日目迄に ammonia-N は急激な増加を示し，300mg%にも達してそのまま数日間は殆んど恒量に保たれ，後期即ち21日目頃より少量の減少を示して居る。これと反対に urea-N は新鮮時460mg%，即ち尿素にして970mg%程度含有して居たものが14日目頃迄に其の大部分が分解され100mg%前後となり，以後極めて緩漫に減少して26日目頃には50mg%程度となつた。urease 活性は初期に於て少々増加して最大を示すが以後urea-N の急激な減少と稍平行して急激に減少し，7日目頃に最低となり以後再び増加を始めるが18～19日目頃から再び減少した。

実　験　II

a）試料及び方法

1953年9月14日漁獲された鮮度の極めて良好なホシザメ，*Mustelus manazo* BLEEKER，を表面良く水洗後，可及的細菌汚染を防ぐため，マツダ紫外線ランプを用いて約5時間殺菌した小部屋にて，実験Iの際と同様調理肉挽し，同じく10gづつに分け一定日数毎に urea-N，ammonia-N の増減及び細菌群の変化を次の様な方法により測定した。ammonia-N の測定は減圧蒸溜法[15]により行い，urea-Nの測定は除蛋白液について，diacetylmonoxime を用いる A. A. Ormsby 法[17]に依り光電比色した。又細菌群の変化の測定は一定日数毎に試料を50ml容の滅菌 homogenizerにて27mlの滅菌生理食塩水と共に5分間良く homogenize し，後常法の如く適当に稀釈して平板培養法により Table 1 に示す5種類の培地に培養してこれに発育する集落の数を測定した。

Table 1. The composition of media

	Medium I	Medium II [19]	Medium III [20]	Medium IV [20]	Medium V [18]
Composition	Beef extract 10g Peptone 10g NaCl 5g Agar 20g Water 1000ml pH 7	Urea 30g K_2HPO_4 0,5g $C_6H_5O_7Ca_3$ 10g Agar 20g Water 1000ml pH 7	Urea 20g $CaCl_2$ 0,1g Beef extract 5g NaCl 0,1g K_2HPO_4 1g $FeCl_2$ 0,01g $MgSO_4$ 0,3g Agar 20g Water 1000ml pH 7	Urea 50g K_2HPO_4 0,5g Soil extract 100ml Agar 20g Water 1000ml pH 7	NH_4Cl 6g $MgSO_4$ 0,2g KH_2PO_4 3g Na_2HPO_4 6g Glucose 4g Agar 20g Water 1000ml pH 7

b）結　果

以上の方法により腐敗進行過程に於ける urea-N，ammonia-N の増減及び細菌群の変化を測定した結果は Fig. 2 に示す如くである。実験Iの際と同様初期3日目位までに ammonia-N は急激に増加し300mg%となり，以後4～5日間恒量の後少しづつ減少し始めた。urea-Nはammonia-Nの増加と対照に初期に於て急激に減少し，以後10日間位恒量の後再び減少して24日間には殆んど全量が分解しつくされた。細菌群の変化は Fig. 2 により明らかな如く尿素細菌群（III，IV及びV群）は初日に於て普通細菌群（I及びII群）の約 1/100 で 10^2程度より認め得なかつたが，腐敗の進行と共に初期3～5日目までに急激に増加し後者と略同数となる。此は丁度初期に於ける ammonia-N 及び urea-N の増減に平行している如く思われる。其の後約16日間は発育が停止，若しくは減少を示し後期に於て再び漸次増加を示した。其の際IV群のみは急激に増加し，I及びII群と略同数となつている。一方普通細菌群（I及びII群）は初期に於て10^4程度あつたものが腐敗の進行と共に対数的に増加し後期即ち17日目で約10^7となり発育が停止して以後次第に減少を示して居る。IV群即ちN源として NH_4Clのみを含有する培地に発育する所謂 non-exacting-bacteria はI及びII群と略同数又は稍下廻つた数で殆んど其等と平行した変化を示して居る。以上の結果の中，初期に於て ammonia-N，urea-N の増減が急激で有ることとは清水[2]，日引[9]，高橋[11]の結果と同様であるが，後期に於て ammonia-N が減少を示して居る事は全然異なつた現象である。又尿素細菌数と普通細菌数との比は木俣[14]等の結果といささか異つて居る。又 urea-Nの減少に於て清水，大石[2]が指摘して居る step と思われる点が観察された。

考　察

以上2回の実験に於て尿素細菌の急激に増加を示す初期に於て urease活性は最大となり，それと稍平行して urea-Nの大部分が消失し，反対に ammonia-N は急激に増大，其後尿素細菌が増殖停止又は減少を始める

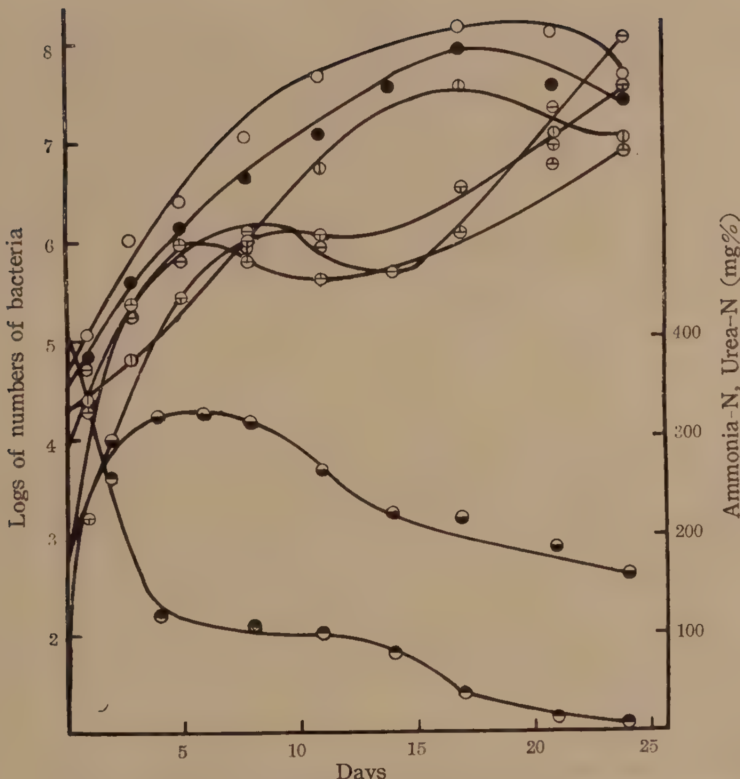


Fig. 2. Changes of bacterial flora, ammonia-N (volatile-N) and urea-N during spoilage of shark muscle at 15° to 20°C

○ Bacterial group Ⅰ, grown on medium Ⅰ at 30°C
● 〃 Ⅱ 〃 37°C
⊕ 〃 Ⅲ 〃 medium Ⅱ at 30°C
⊖ 〃 Ⅳ 〃 Ⅲ 〃
⊕ 〃 Ⅴ 〃 Ⅳ 〃
⦶ 〃 Ⅵ 〃 Ⅴ 〃
◒ Ammonia-N
◓ Urea-N

頃に urease活性は急激に減少し，後期に於て尿素細菌が再び漸次増加を示し，又普通細菌の増殖が最大となる頃にurease活性も又再び増加を示した。実験Ⅱに於ては其の頃に減少が一時停止して居たurea-Nが再び減少を示した事等から考えると，鮫肉に於ける尿素の分解の大部分が細菌の酵素によるものであろうと思われ細菌組成の変化と urease活性との間には密接な関係が有ると予想出来るが，其の間に於ける関係がどの様なもので有るかと云う事は以後の実験にまたねばならない。然し実験Ⅰに於ける初期urease活性の変化は清水，大石[7]等の結果と稍一致するもので，同氏等は此の変化は細菌の増殖によるものであろうと述べている。又 Gale が其の著書[18]に於て細菌の発育齢と，乾燥菌一定量当りの酵素量との間について二つの型の関係を述べており，第Ⅰ型の酵素は発育早期の培養が高い活性を示し，培養の生長につれて此の活性が弱まり細胞分裂が停止した後は低下するので，此の型のものは細菌の発育の為に細胞が持たねばならぬ同化酵素の特徴で有り，第Ⅱ型の酵素は発育早期の細胞は殆んど其の酵素活性がないか，全く酵素を持つて居ないが発育中に

次第に作られ細胞分裂が停止する時期にその量が最大となり発育が終つた後は又活性が弱まるもので，此の型の様な変化をする酵素は発育時の合成過程に直接関係がない異化，或は防禦機構に関係するもので有ると述べて居るが，此の説が妥当で有るとすれば， 著者等の実験に於ける初期の urease 活性の変化は尿素細菌（Ⅲ，Ⅳ及びⅤ群）の発育に起因するⅠ型の変化であり，以後に於ける変化は普通細菌の発育に起因するⅡ型の変化によるものではなかろうかとも考えられる。此の点については今後個々の細菌について究明したい。次に ammonia-N が他の多くの報告と異り後期に於て減少を示しているが，再度の実験に於ても同様の現象が見出されたので著者等の測定法に起因するものとも思われず，本研究に於ては試料の調製に際し殺菌ランプを用いる等，特に空中細菌の汚染を防いだのでFig. 2に見られる如く普通細菌の殆んどが海洋に由来すると思われる non-exacting-bacteria であつた為，ammonia-N が此の種細菌に利用されたのではないかとも考えられ，此の事に関してはいずれ機会のある時に更に究明したい。尚実験Ⅰと実験Ⅱの変化の間に時間的に若干のずれが認められるが，これは後者の試料放置温度が前者に比して高かつた為ではなかろうか，終りに望み本研究遂行に当り終始実験器具を貸与下され，又助言を賜わつた本学大石講師に衷心より謝意を表する次第である。

要　　約

腐敗過程に於ける鮫肉の水抽出液urease活性の変化及び細菌相の消長を観察した結果は次の如くである。

1） 鮫肉抽出液の urease活性は初期4日目頃まで稍増加を示して最大となり，以後急激に減少し20日目頃に再び僅かの増加が認められたが，その増加は間もなく低下した。

2） 細菌群の変化は初期に於て尿素細菌が急激に増加して普通細菌とほぼ同数に達したが，以後恒数，若しくは減少して普通細菌の1％程度となる。然し後期に於て普通細菌が減少を始める頃に再び少しづつ増加を示した。又N源としてNH_4Clのみ含有する培地に良く発育する細菌群は普通細菌より稍下まわつた数で，それと略同様の発育を行う事から普通細菌の大部分が此の群の細菌により占められるのではないかと思われた。尚こゝで普通細菌と呼ぶものは普通寒天培地によく発育した細菌群であり，尿素細菌とは尿素を含む培地によく発育した細菌群を呼ぶものである。

3） 以上の結果から細菌組成の変化と水抽出液の urease活性の間には密接な関係が有ると考えられ，鮫肉の腐敗に於ける尿素の分解の大部分が細菌の酵素によるものであろうと推察した。

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特殊の事情下に於ける危急避航操船処置に関して

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On Emergency Ship Handling Procedure to Prevent Collision at Sea under Special Circumstances

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Abstract

When two vessels are approaching each other so as to involve imminent risk of collision, one of them, the privileged vessel, is obliged to take such co-operative action with the other, burdened vessel as will aid to avert collision. However, it is not easy for the privileged vessel to determine the instant when that action should start. Also it is more difficult for her to demonstrate that she should not continue to proceed on her way, but as to the action she takes in that case, whether it is allowable or not is a subject that must be clarified.

The author presents an opinion as to the co-operative action under such circumstances as follows: that is, a co-operative action to avert collision must be always intentional, which lets the burdened vessel act on the Rules and only when she is definitely confirmed not to change her will against the Rules, is the privileged vessel permitted to depart from the Rules in accordance with Rule 27. Reducing her speed and putting here engines into reverse in the case of immediate danger of collision are in most cases too late and less effective, while, if too suddenly done they produce a cause of collision, or a contribution to the collision which is likely to follow.

はしがき

衝突予防法上の航法を文字通り其のまゝ厳格に適用し得ない様な特殊な事情のもとに於ても衝突を避けるため，あらゆる努力を払うべきことは同法第21条後段，第27条及び第29条の趣旨より各船に対する当然の義務である。

然しながら其の時機，其の方法等如何なる処置をすべきかに関しては，其の時の事情や条件が単一であり得ないので，一定の法則として成文化されておらず，只其の各場合に対応する最善の努力を払うべきことを要求しているのみで，船員にとつては，あらゆる場合に其の衝突結果に対して責任が追及せられるので，反つて避航処置に消極的となり，事故増発のおそれなしとしない。

筆者は斯る情況の内で，特に他船に対して保持船たる側の指揮者が協力動作として為すべき処置に関してこれを積極的に実施するための条件を検討せんとするものである。

避航処置の概略

第21条後段の要求に従つて，保持船としての協力動作を行うに当り，種々の見解があるが，2つの方向に分けられる。

其の1は，何等か臨機の処置を為して後，不幸衝突事故の発生した場合には，それが衝突の原因又は援助となつたものとして過失ありとせられるのに対して，最後まで何等の処置をも為さなかつた場合には，万止むを得なかつたものとされること多く，且短時間内に如何なる処置を実行することが最も適当であるが，其の判断の困難さから同条の前段を固守して，最後に，衝突直前其の効果の如何に係らず，機関を全力後退にすべしとするものであり，其の2は Davis Newton Lott の提案する如く，衝突点までの保持船の針路より，或る距離（500 yards を一基準として示しているが，之れは当然船舶の大小，性能其の他の事情によつて相異

がある筈である）の安全帯を想定して，是の特定の範囲内にまで接近したならば協力動作を始むる可能性ありとするものである。

前者に対しては第21条に明示せられている如く，強制的のものである以上，これを遵守しないことは許されず，必ず何等かの協力動作を行うべきことは当然である。只協力動作の要求せられるのは，航法が適用されない場合であるから，航法の原則に違反することのみが協力動作であるとするならばそこに問題が残る。Marsden P. 546に記述せられている如く，通常の注意によつて避けられる如き所謂臨機の処置の不実行は過失とせられる。

The John Buddle 事件で Dr. Lushington の言ふ如く，“予防法からの離脱が必要であつたと断言出来る事情が証明されない限り，これに出来る限り執着することは重要事ではあるが，同時に臨機の処置をとらなかつた事情をも証明する必要があろう” と (marsden P.544).

又全く一方の義務怠慢によつて，危険に曝らされた場合であつても，（是の場合第27条後段が強制法となつて）衝突の危険防止の処置を何等とらなければ，正当なものとは認められない。

何れにしても，其の時の事情を如何に処置すべきかの判断をする義務が厳重に課されているのである。即ち法の固執より，最後は適当な船舶の運用により衝突防止の完全を期しているのである。すでに避航船の処置のみでは，衝突が避けられないのであるから，協力動作とは，必ず何等かの処置をすることであり，針路速力の保持によつて，衝突が避けられると云う期待は全く残されておらない。

其の処置判断は，規定の言及し得ないところで，総て通常有すべき知識，経験，熟練，注意及び勇気等を有する船員が，適当な船舶運用の法則に従つて，協力動作は行わるべきものとして，具体的の規定はなされていない。

協力動作の時機

是の点に関しては，Lord Buckmuster の言う如く，是の規定は数学者のためのものではない。其の時機に就いては，或る特定の瞬間を算出すべきでなく，船員の指導のために作られたものであることは十分に考慮さるべき点であるが，又同時に其の時機は合理的に計算されたものであるべきであり（Marsden P. 518）それ程に厳密な意味のものでないことである。即ち或る計画性のあることで足り，其の時の状況を判断して，採るべき処置の結果に避航の可能性を見出し得るものでなければならぬが，数学的に寸秒を争う如きものではないのである。

第27条の要求に従つて，本航法に違反した協力動作を行う必要ある場合は，其の必要性を証明しなければならぬ。即ち相手船の違法の処置を確認しなければならぬ。法を守るべきか，或は之れに違反すべきかは，急迫してから判断することは蓋し至難事である。遅きに過ぎ易い原因の一つとして其の時の合理的な計算，即ち避航の可能性を見出すための計画に欠けている点が挙げられる。若し其の正しい計画があれば，斯る時機まで無為に過す筈がないからである。是の見地からも有能な“見張り”の重要性が痛感せられる。

今２隻の動力船が，互に其の前面に視認しつつ，接近して其の Rangeが避航船の最大舵角時の最大縦距，又は全力後退時の停止距離となつたならば，避航船の処置のみにては，殆んど衝突は決定的になろう。斯る場合には其の時が協力動作発動の時機として最も妥当である。然し其の交角が90度以下の場合は，より接近しても航法に従つて単独で避航の可能性あり必ずしも是の Rangeを以つて直ちに其の時機と決定することは出来ない。又避航船の性能を確認することは極めて困難であり，其の他其の時の事情や条件等の相異によつても厳密な時機の決定は殆んど不可能であるが，斯る Rangeが１つの要素と考えることは出来る。若し避航船が明らかに航法に違反して其の意志，行動の変更が認められないならば，其の時が協力動作発動の時機である。

協力動作の手段

避航船が単独では衝突が避けられない場合，保持船としての処置には，２つの場合がある。即ち避航船があくまで航法に従つて行動しようとすることに協力する場合と，避航船が航法に違反した避航処置に出た場

合とである。後者の場合は第27条の規定によつて，航法の違反が保持船に対して容認され且つ要求されるのである。

協力動作である以上，衝突の原因又は其の援助となる如き処置は許されない。最善の協力動作なる語句は重要なものである。本条の文面のみでは航法の原則に準じてとつた行動による協力動作が要求されているのであるが，第27条後段の規定が之れに追加されて，たとえ相手船が違法の行動をとり，其のために起きた衝突の虞れであつても，それを避けるためには，航法の原則から離脱しても，協力すべきことが含まれるのである。

そこで，航法に準じて，とつた協力動作の場合は比較的問題は少いが，是れから離脱して協力しようとした場合，其の判断に少しでも誤差があると，避航の協力とはならず反つてその衝突の原因又は援助となるのである。

相手船の行動を判断する上に，多分斯く斯くの行動をとる筈であろうとの臆断によつて処置すべきでなく現実に斯る行動中である，或は斯る行動をとる意志を表明していることを確認してのみ処置をすべきものである。且其の処置も第1に航法の原則に準じたものであること。第2に若し其の原則に違反しなければならない特別の理由が明確になつたときのみ，之れから離脱して行動し得るのであつて，多少の時間的過早は，最重要事とは考えられない。

両船間の関係が其のまゝ続いたならば衝突が決定的である場合に，とつた行動が其の後起きた衝突の原因又は援助とならなかつたならば明らかに過失と認められることはない。

協力動作は常に其の衝突を避け得る可能性あることが前提でなければならぬ。協力すべき船は保持船であるから，当然他船は其の船の左舷側に在る筈であり，如何なる操船がなされる場合に於ても，航法の原則に違反することとより，これを遵守する可能性が多い。航法の基本則の1つは右転して左舷側を相い対して航過することで，且つ他船は第22条及び第23条に従つて，保持船の船首を横切ることのない様に努める筈であるから，交角の如何に係らず左転は禁ずべく，右転すべきものである。之れが航法の原則に準じて採つた行動である。

若し避航船が航法の原則に違反して，第28条第2項の疑問信号を吹鳴したにも係らず，其の意志の変更が認められない様な場合のみ，最後に航法に違反してもあらゆる避航処置が要求せられるのである。而し確実に避航し得る事実ある場合以外は左転は厳禁すべきものである。

航法からの離脱が要求される特殊の場合とは，第21条後段の協力動作と言うより，第27条によつて容認された違法の動作が要求される場合，例えば避航船が危険切迫してから航法の原則に反して保持船の前面を横切る様に左転して来る如き場合であつて，臨機の処置が要求される急迫した状況に於て，斯る行動がとられたならば，最早や衝突は決定的であり，損害の減少だけに対してでも最後の努力を払うべきものとされている。

一般に試運転中の全速力後退の場合でさえ，発令後10秒乃至20秒間は殆んど船速は低下していない。まして，航行中突然の発令に際して，機関作動までの経過を考慮するならば，相当の時間を必要とすることは当然であり，尚船体は其の原針路上に沿うて前進を続ける。これに対して針路変更は時間的にも距離的にも，いつでも比較的試運転成績表に近い結果が得られて信頼性に強く，船体は其の最大縦距の½乃至⅔の進航距離に於て完全に原針路上より離脱し得る。即ち転舵した場合は，船の長さの2乃至3倍の前進距離に於て原針路上より離脱し得て避航の可能性を見出し得るが，全速力後退のみでは，其の位置附近に於ては尚原針路上に残り，僅かに船速を低下し得て，多少の損害減少が希望出来るに過ぎないことは，十分に考慮されなければならぬ点である。

本来衝突予防法は，衝突其のものを避けることが主目的であるから，其の時機の遅速も重要事ではあるが其の手段処置が，より重視せらるべきである。The Otranto 事件に於て，英国上院が控訴院の判決に反して両船間の距離½海里乃至¼海里に於て，とつた Otranto 号の臨機の処置の時機を正当と認めておる。只其の時の事情が必要とする如く，機関の停止又は反転に失敗したこと，及び極左転にした過つた行動は非難さるべきものとし，同時に他船に対しては其の避航が余りに遅きに失したと判決している（Marsden P.517）こと

は注目すべきことである。

協力動作の適否は，其の処置が一般航法に照らして，正当であつたか，或は適当な船舶運用の法則に従つたもので，船員としての見地から正しかつたか，非行であつたか，且つ其の時の判断が正しかつたか否かによつて決定せられる。規則からの離脱が容認せられる場合でも，適当な船舶の運用と其の判断からの違反までも容認しているのではない。

例えば他船の行動に対して，これに遠ざかる如き処置であつたか，或は反つて接近する如き操船が行われたかによつて容認せられるか否かが判定される。従つて衝突が切迫したならば，相対速力を出来得れば負にする様に努めるべきで，被追越船の速力減殺の如きは甚だしく不利である。

是の判断は非常に重要性のあるものであるが，前述せる如く，合理的な計算をするにも，其の前提となる“見張り”が厳重に守られてこそ，その判断が正当なものとして是認せられるのである。見張りに怠慢があれば，其の判断は正確を期し難いのは当然である。

前記の如く，速力変更の直接目的は衝突其のものを避けるより，相対速力を減少せしめて，衝突地点に到達する時間を延長せしめるためのものである。従つて機関を反転して船体を後退せしめることは180度の其の場回頭として最も意義がある。

不幸にして衝突した場合，速力を減殺しておれば，有利に判定されるのは，其の損害程度を減少せしめ得たこと及び其の衝突の原因又は援助とはならなかつたと云ふ見地からで，衝突其のものを避ける効果が多いとは云えない。

保持船が其の速力を減殺する場合を考えると，これによつて避航船をして，時間的の余裕を得せしめて，適当な避航処置をとらしめるにあり，従つて協力動作となる点にある。其の発動効果に余り期待の出来ない様な，極く切迫してからの速力変更が必ずしも避航処置としての成算あるものとは考えられない。且つ早きに失した速力の減殺は，航法に従つて其の後方を航過しようとした避航船との衝突の原因或は其の援助となる可能性が強い。

The Commerce 事件は，英国下部法廷で，保持船が最後まで其の針路速力を保持したことは過失であつたと判決したのに対して，枢密院は明らかに違反の必要な場合を除いては，其の判断の困難さを指摘して，前審を覆えしている。北野丸事件に於ては，保持船たる義務に違反したことは正当であるが機関の停止又は反転をしなかつたことと，左転舵にしたこととは適当な船舶運用の必要条件を破つたものとされた。そして同じ様な事情では，右転舵が怠慢とされたことのないことは注目すべきこととしている。而かも左転舵が怠慢な行為であると規定することは困難ではあるが，左転舵の許された，只一つの The Rayford 事件に於ても Scrutton L. J. は衝突に影響しない程軽いものであつたことを指摘している(marsden P. 553)。

航法からの違反は命令でなく容認の形式をとつている。衝突事故が発生した場合，避航船が航法の原則に従つた行動の出来る様な協力動作であれば，保持船に対して其の時の事情が考慮されるが，これに反した行動に対しては，それが衝突の原因又は其の援助となるものではなかつたと云ふ証明のない限り過失ありとされる。而かも衝突が起きたと云う事実は其の証明を甚だ困難にしている。

要　約

前例は場所的にも相対的にも其の性質が全く異ることが多いので，其のままいつでも適用せられるものではないが，協力動作に関して次の事が言えると思う。

即ち避航船が明らかに航法に違反している事実なき限り，保持船は協力動作としては，避航船が航法の原則に従つて行動出来る様に右転すべく，若し右転し得ない特別の事情にあり，又は避航船の違法の意志変更が認められない場合，時機早きに過ぎても機関を反転して，時間的余裕を与えるべきである。

極く接近してからの機関反転は避航と云う点では余り実効は望めない場合が多い故有能なる見張りによつて早期に他船の行動確認に努めるべきである。

理由　1.　客観的にそれ以上の接近が許されなかつたことの証明が困難であり其の時の事情によつては，多少の遅速は過失とすべきでない。

2. 船舶運用上成算あり，且つ衝突の原因又は其の援助となる可能性が少いこと。

尙他船の船首方向が少しでも正横より後方に向けて移動する如き場合は後退すべきでない。

む　す　び

判例は殆んど機関を反転しなかつたことは責任あるものとしている。これは衝突までの時間的余裕を得せしめて善処する機会（航法に従つた処置）を与えることと，速力がなければ衝突の事実が起きないと云うことから推奨されているものと考えられる。筆者は右転舵を余りに強調し過ぎたかも知れない。而し機関の反転を不必要であると主張したものではない。只危険が余りに急迫してから，単に機関を反転にしさえすれば責任を免れ得るとする如き安易な考えを持つべきでないことを警告し，積極的の処置による衝突事故の減少を念願するものである。

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音響測深機による魚群量の近似的評価について

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An Experimental Study for estimating the Approximate Amount of Fish Shoals by Echo Sounding Method

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Abstract

The method of detecting and locating fish shoals by echo sounder has been widely used for the purpose of an aid to quick and reliable fishing. It is useful technically for fishing engineers to estimate quantitatively the amount of fish shoals to some extent by observing and roughly calculating the echoes on recording paper. In the present paper a method of rough estimation on the size of fish shoals by echo sounder was described, and results of experiments by this method on the mackerel shoals on the fishing ground in Ishikari Bay was also reported.

1 緒　　言

音響測深機に現われた魚像より，その実際の魚群量を極く近似的にでも推定することが出来れば，漁撈技術上有益である。記録紙上に現われる魚像は，基本的には魚群の立体的分布に基いて，魚像の大いさ，形状並に記録像の濃度を以つてその構成を現出してくるが，同一魚群でも，異つた機器で記録されたものに魚像の差が認められることは屡々経験することである。又記録時の諸条件に依つても影響を受けるものである。魚群量の推定に大きい関係を持つ魚像の大いさに就いては，魚群の分布状態のみならず，魚群の移動速度に対する船の相対速度や，記録紙の送出速度等が大きい関係を持つ。記録像の濃度は魚群分布密度や魚体に音波の入射する方向等が関係してくる。魚像の形状は魚群構成に関する生態学的問題であるが，玆では，魚群量に関係する立場からのみ触れるに止める。

2 魚群量の推定に就いて

1°） 魚像の長さに就いて

今魚群が水中に於て，任意の立体的分布をしている時，記録された魚像と実際の分布との間には，どのような大凡の関係があるものかを考えて見る。今船が魚群上を航行したとして，船速を v^{knot}，記録紙の送出速度を $u^{mm}/_{min}$，魚群の移動速度を $v'^{m}/_{min}$ とする。船は送受波器の指向角に相応するビームを以つて魚群上を走査していくのであるが (Fig. 1.) 魚群が静止しているものと考える時，船が走査して行くであろう魚群の長さを L meter とすれば (Fig. 3.) 若し簡単のために船の進行方向と魚群の移動方向とが一致しているものとすれば，魚群を走査するに要する時間は

$$\Delta t = \frac{L}{\frac{1852 \times v}{60} \pm v'} \quad (\text{min}) \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

となる筈である。

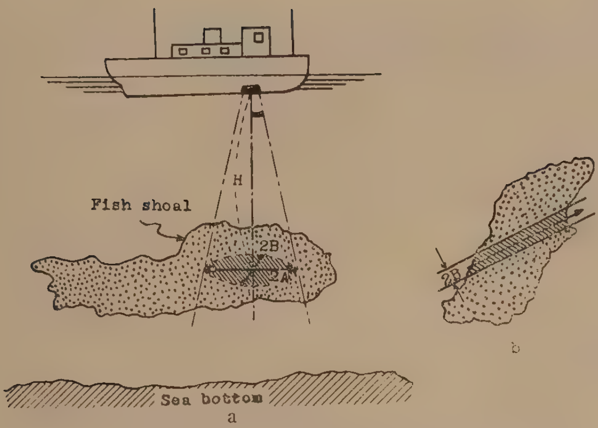


Fig. 1. Distribution of fish shoal in the sea and scanning of sound beam projected out on them
a: Vertical section　　b: Plan section

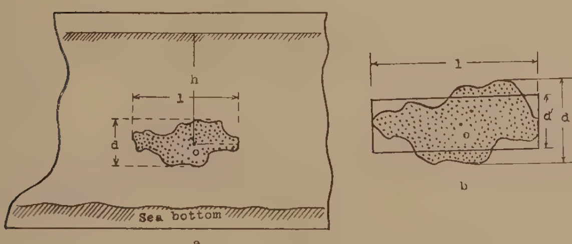


Fig. 2. Size of echo of fish shoal recorded by echo sounder
a: Vertical section
b: Rectangular dimension (l×d') equivalent to actual size of echo

但し分母のv'の符号は，v'がvと同方向の時は負，反対方向の時は正となるは勿論である。

この時一方，記録紙上に現出する魚像の長さをl mmとすれば，記録紙の送出速度は $u^{mm}/_{min}$ であるから (1)の走査時間は

$$\Delta t = \frac{l}{u}\ (\mathrm{min}) \cdots\cdots\cdots\cdots (2)$$

でなければならない。

従つて魚群の長さLと記録紙の魚像の長さlには次の関係がある筈である。

$$L = \frac{l}{u} \times \left(\frac{1852 \times v}{60} \pm v' \right) \quad (\mathrm{meter}) \cdots\cdots\cdots\cdots (3)$$

実測によれば魚群の移動速度は普通 20〜30 $^{m}/_{min}$ 程度が多い由の報告があるが[1] 若し船速がそれに比べてかなり大きい時は (3)は近似的に

$$L \fallingdotseq \frac{l}{u} \times \frac{1852 \times v}{60} \quad (\mathrm{meter}) \cdots\cdots\cdots\cdots (4)$$

と考えても良いであろう。又船の進行方向と魚群の移動方向とが，ある角度θをなしている時は，魚群の実際的形状と，v, v'及θの如何によつて走査する長さと時間とが決つてくるであろうが，大凡の関係は次の如くなる。

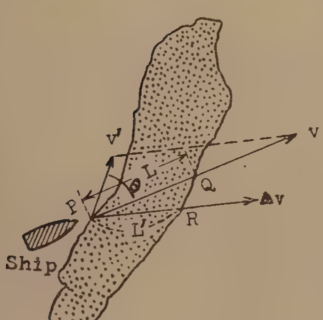


Fig. 3. Angle (θ) between ship's course and direction of movement of fish shoal on plan section

船速の魚群移動速度に対する相対速度は

$$\overrightarrow{\Delta v} = \vec{v} - \vec{v'} \cdots\cdots\cdots\cdots\cdots\cdots (5)$$

であるから$\overrightarrow{\Delta v}$の大いさは

$$\Delta v = \sqrt{v^2 + v'^2 - 2vv'\cos\theta} \cdots\cdots\cdots\cdots\cdots\cdots (6)$$

であつて，この大いさを以つて PR=L'(Fig.3.)上を走査することになり，この走査時間に対応した魚像の長さを記録紙上に現出するものと考えればよいが，普通の垂直式のものでは，魚群の移動方向は確め難いから一応(3)又は(4)で魚群の長さを考えて置くことにする。

2°) 魚像の厚みに就いて

魚像として現われた魚群の厚みは長さの方向に対して一般的に不均一で魚像の厚みをどこにとるかは，実際上取扱いに困難な問題である。勿論実際上の魚群の立体的分布を反映していることには間違

いないが，一般に魚像の上辺部は記録が濃く出るが，下辺部は薄くなつて，厚みがはつきりせぬ傾向を生じ易く，且パルス幅に応じて像が長びく。実測的な意味をより多く持つ魚像の長さの方を重く見て，魚像面積と等しい等価矩形を考えて，その等価的な魚像厚みd′を一応魚像厚みとして考えて置くことにする(Fig. 2.)。

3°) 魚像の幅に就いて

船が魚群上を走査する場合，1回の走査に依つて cover し得る幅は船の進行方向と直角な方向に対して持つ送受波器の指向角と魚群位置の水深とで決まる幅となるべきで，魚群の幅が大きい時は魚群上をこの幅で分割して走査すればよい。普通の送受波器は音響輻射面が矩形か，円形かの何れかで音響ビームが集束される程度を示す指向角は次の式で示される。

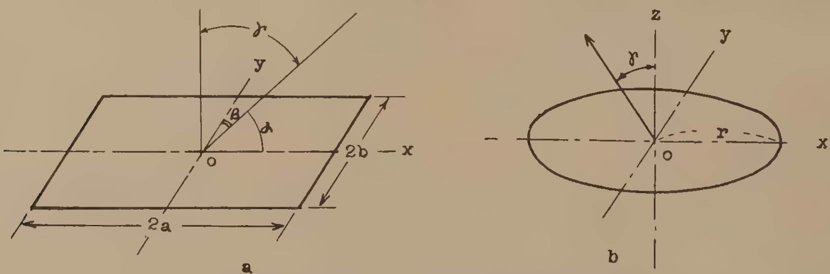


Fig. 4. a: Directive angle of rectangular projector
b: Directive angle of circular projector

(a) 矩形の場合〔Fig. 4. (a)〕

矩形を 2a×2bとし 輻射面に垂直な軸を z とする。今 x, y, z 軸と α, β, γ なる方向の音圧と，z 軸方向の音圧の比を $R(\alpha, \beta, \gamma)$ とすれば

$$R(\alpha, \beta, \gamma) = \left| \frac{\sin u}{u} \cdot \frac{\sin v}{v} \right| \quad \cdots\cdots\cdots (7)$$

但 $\begin{cases} u = \dfrac{2\pi a}{\lambda} \cos\alpha \\ v = \dfrac{2\pi b}{\lambda} \cos\beta \end{cases}$

特に x - z 面内のみの指向性は $R(u) = \left| \dfrac{\sin u}{u} \right|$

又 y - z 〃 $R(v) = \left| \dfrac{\sin v}{v} \right|$ ……… (7′)

となる。R(u) 又は R(v) を $\frac{1}{2}$ にする様な γ を半減角といゝ，ビームの集束度を示す実際的の尺度となつている。

(b) 円形の場合〔Fig. 4. (b)〕

輻射面に垂直な z 軸となす角を γ とすれば，指向角は次式で求められる。

$$R(\gamma) = \left| \frac{J_1(x)}{x} \right| \quad \cdots\cdots\cdots (8)$$

但 $x = \dfrac{2\pi r}{\lambda}$ J_1は第一次ベッセル函数

この $R(\gamma)$ を $\frac{1}{2}$ とする様な γ を以つて半減角[2]という。

何れの場合もこの半減角がビームの集束度を表わすもので，このビーム内に含まれているものは反射映像を示すものと考えて間違いない。つまり半減角を γ とする時，幅 $2B = 2H\tan\gamma$ で走査することになる。実際的な魚群幅は水平音探を用いて実測するよりないであろう。

4°) 魚像の走査容積について

以上 1°), 2°), 3°) で述べた如く，一回の走査によつて得られた魚像は，少くとも，魚像の長さ l, 魚像厚み d′, 及走査幅 2B で作る容積の中に入つていることは略間違いないであろう。それ故 n 回の走査で，魚群を走査し得たとすれば，全走査容積は

$$V = \sum_{1}^{n} V_n = \sum_{1}^{n} L_n \times d_n' \times 2B_n \quad \cdots\cdots (9)$$

となる。従つて理論的には，魚体の平均密度を ρ, 魚群の分布密度（単位容積内で占める容積比）を K とすれば魚群の全重量は

$$W = V \times \rho \times K \quad \cdots\cdots (10)$$

となる筈である。

5°) 魚像の濃度に就いて

魚群よりの反射強度は，普通反射損失なる量によつて表示されるが[3] 既知の分布密度の反射損失を予め測定しておき，実測せる反射損失より逆に大凡の分布密度を推定出来よう。

魚像記録の各部分の濃度は異るから平均の濃度（反射損失で表わした）は次の如くなる。

$$\Sigma = \frac{1}{A}\int_{A} \sigma \, dA \quad \cdots\cdots (11)$$

但 σ：反射損失が均一と見られる微少面積毎の濃度

実際は 3 ケ所位の濃度の平均をとつて十分であろう。つまり，この平均濃度より大凡の分布密度を逆算する訳である。

3 実験について

魚群量の確認は，最後に捕獲したものを実測しなければならぬから旋網による鯖群について，実験を行つた。小樽の青山漁業K.K.の好意により，音響測深機を装備せる小伝馬船を旋網で魚群を囲つてしまつた後から最後に網を上げて行つて，伝馬船が網中に居れなくなるまで，網中で魚像の記録をとつた。

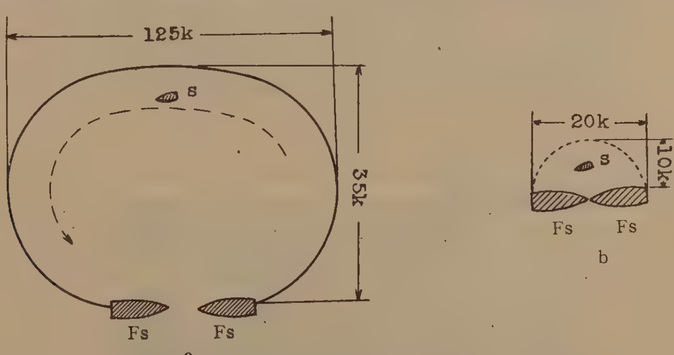


Fig. 5. "Aguri" net (Ring net) for mackerel fishing

a: Net surrounds the fish shoal.
b: Fish shoal is concentrated near the fishing boat.
FS: Fishing boat. S: Position of observation boat.

漁業学教室の御教示によれば鯖群は，網に入らぬ前は帯状群が普通で，網へ入つてから網を締めて行くに従い，次第に環状群となり，Fig. 6(b) 網の略周囲に沿つて環状的に移動するものゝ如く，網が極度に締められてくると，水面近くに群がる様になる(Fig. 7)。Fig. 6(a)は網でまいて後，網をかなりしぼつてからの像で，Fig. 5 の s の位置でとつた記録で，代表的な鯖群の魚像である。Fig. 6(b) は環状群になつてからそ

れが約規則的に游泳しているものゝ代表的魚像形状である。Fig.7は魚群を船に取り入れようとする少し前で魚群は殆ど表層近くに集り，且つ一定した群形はない。尙 Fig.6 (a) 及 Fig.7 は反射損失の測定のために，反響を消す操作を行つたので，魚像の一部が消えている。Fig. 6(b) の魚像について大凡の計算を行つてみる。

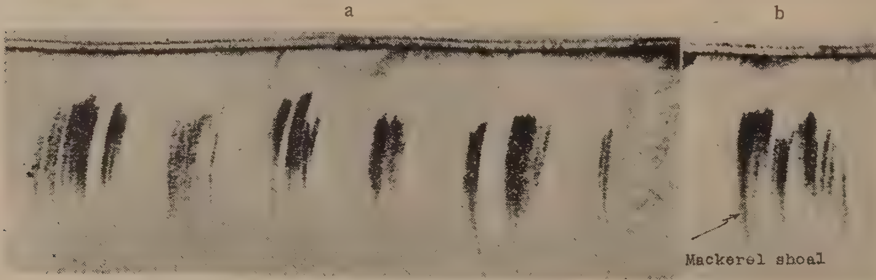


Fig. 6. Figures of echo reflecting shoals of mackerel in the middle depth in the beginning of net cast at time corresponding to (a) in Fig. 5

a: Six groups of figures show that a fish shoal altered position six times under the echo sounder.

b: A figure of fish shoal used in the calculation of amount of shoal.

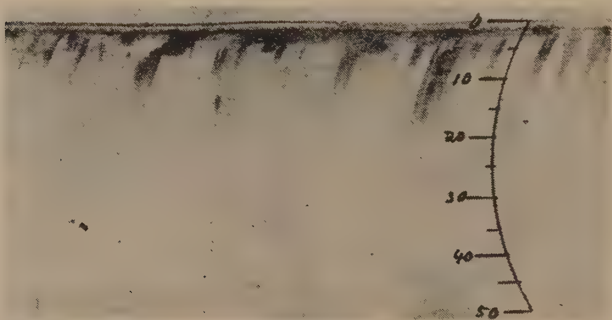


Fig. 7. Figures of fish shoal near the sea surface at time corresponding to (b) in Fig. 5

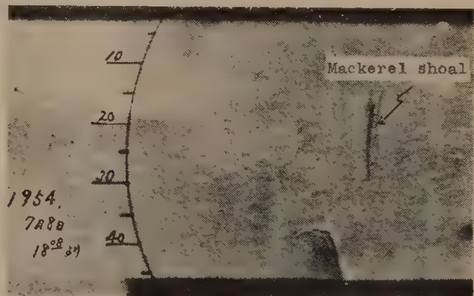


Fig. 8. Figure of small shoal of mackerel in the middle depth

使用した音響測深機は海上電機製のフイシユカメラで，周波数 50kc（波長約3cm），記録紙の送出速度は $12^{mm}/_{min}$，送受波器は矩形で指向角は16°×28°のものである。

鯖群は中鯖で体重200～270匁のものであり，反射損失は平均－20db程度で之は1立方米に約30尾程度のものである。尚魚像観測用の小伝馬船は殆ど静止して，魚群移動速度によつて魚像の長さが決まる例である。

魚像の長さ　$l=21.5^{mm}$
記録紙送出速度　$u=12^{mm}/_{min}$
魚群移動速度　$v'=40^{m}/_{min}$
} より　魚群の長さ　$L=1.95\times40\fallingdotseq78$（m）

魚像の厚み　$d'\fallingdotseq7.7$（m）

尚漁業家の種々の経験や，垂直音探を水平音探にして実測した経験などを総合して，鯖群の幅を平均7m ととつた。然る時は魚群は略 78m×7.7m×7m の容積内に収まることになり，魚群分布密度係数Kは，平均体重240匁（比重1.08）のものが約30尾として，$K\fallingdotseq\frac{1}{34}$　　$\rho=1.08^{gr}/_{cm^3}$　として

魚群の全重量は

$$W=78\times7.7\times7\times1.08\times\frac{1}{34}\fallingdotseq3.3\times10^4\text{貫}$$

捕獲物の実際重量は略1万6千貫程度であつた。

又比較的小群の場合（Fig. 8）も同様に計算してみると大凡5400貫となるが実際に捕獲したものは2300貫程度であつた。

4　考　　察

一例として鯖漁の場合に就いて実験で確めてみたが，極く大雑把な考え方ではあるが，この例では桁違いに推定が異つているという結果にはならなかつた。然し考え方自身に近似がかなり含まれているし，又実測値にも不備な点が多いので，この例だけでは，未だはつきりしたことは分らない。即ち魚群幅が相当信頼出来る測定が出来るように，水平魚探の装置で測定すること，並に魚像の濃度については，各魚種並に個体の大いさ，及分布等に対しても，統計的に色々な場合を実測し，比較すべき標準を作つておくことなどが漁撈技術上どうしても必要であろう。

尚不規則な而も平面的に分布の広い魚群を走査する場合の考え方は，魚群は移動しているから実際上無理があるが，底棲魚などには応用出来るかも知れない。

尚魚像の濃度についても反射損失と分布密度の関係を推定する場合，反射強度に有効な有効面積の考え方[4]を入れねばならない。之等は尚推定を精確にして行く上に考えねばならない因子である。

5　結　　言

以上述べた如くに，音響測深機に現われた魚像より魚群量を推定する大凡の考え方について述べ，鯖漁に対して行つた実験に就いて比較してみた。まだ少数例なので，不十分な点が多く，且，今後明かにして行かねばならぬ点も多々あるが，取敢えず報告して御教示をいたゞくことにした。本実験には，小樽の青山漁業K.K.から非常に好意的な御協力をいたゞいた。尚鯖漁の実際については，本学部漁業学教室から種々の御教示をいたゞいた。共に厚く謝意を表する。尚本研究に就て筆者の一人は文部省の科学研究助成金を受けた。附記して謝意を表する次第である。

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船の上下動に伴う横動揺の不安定に就いて

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On the Instability of Ship's Rolling due to the Heaving caused by Waves

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Abstract

It is very important to know the amount of instability of a ship resulting from various sea conditions. As connected with the manoeuvering of a ship, the author studied from the view point of dynamics the instability of rolling due to the heaving caused by waves.

It is considered that the transverse metacentric height is reduced on any wave crest when ship is lying transversely on the wave, and the loss of GM is given as follows, under the condition defined by G.S. Baker.[1]

$$\triangle m = 20 \cdot h/L_w^2 \,[\,0.42\ BM + 0.07\ D\,]$$

where;
$\triangle m$: Loss of GM
h : Wave height
L_w : Wave length
BM : Transverse metacentric height
D : Draft in still water

But, the loss of GM is periodical and has the same period of encounter as the wave or the time between the passing of successive wave crests.

Then, considering this loss of GM, the author assumed that GM was given as follows :

$$m_w = m \pm \triangle m \qquad + : \pi/P > t > 0$$
$$- : 2\pi/P > t > \pi/P$$

where;
m_w : GM under above mentioned condition
m : GM in still water
$T_w = 2\pi/P$: The period of encounter as the wave

Further, the equation of rolling motion was given as follows:

$$d^2\theta/\,dt^2 + Wm\,(\,1 \pm \triangle m/m\,)\,\theta = 0$$

Solving this equation, and given the boundary conditions, the author finally got the critical range of period for ship's rolling due to the heaving caused by waves. It is shown in Fig. 1.

According to these theories, the author calculated each value for two kinds of fishing boats and discussed their instability.

I 緒 言

船舶運航者にとつて，所要の船舶の航海性能を知ることは，安全航行の遂行に最も必要であるが，之を須知することは非常に困難である。船舶の復原性の安全に関して多くの研究がされている。例えば J. Rahola[1] は多数の遭難船に関する資料に就いての統計的研究から最小の静的及び動的復原挺を提案し，渡辺[2] は復原性の安全示数を提唱している。特に，小型航洋船に就いては，加藤[3] が多くの資料の理論的調査の結果，船に対する適当な標準を定め，之に就いて横傾斜を与える原因として，定常風，突風，旋回による遠心力，舵圧，及び波浪を考え，船の復原性能に対して最も，severe な条件の下に於て，限界線を決定し，この線に就いて船の復原性の適否を判定している。

著者は，之等の静力学的考察に対して，波浪による船の上下動によつて起るGMの週期的変動に伴う横動

揺の安定性を動力学的に研究した。

II 船の上下動によるGMの変動

船が波浪によって上下動をする時，波頂に於ける船の水面からの浮上りと，船に対する浮心降下によって GMの変動が起る。このGMの変動は G. S. Baker[1] によって，次の条件に於て与えられている。即ち

(1) 所要の船は，船の中心線を波頂に平行に航行している。

(2) 吃水線附近では，側壁が垂直である。

(3) 船巾の範囲内では，波の傾斜面の曲率は無視出来る。

(4) 船に排除される水に作用すべき力は，船に対しても作用している。

$$\triangle m = \frac{20hD}{L_w^2}\left\{0.42\ BM + 0.07D\right\} \quad \cdots\cdots (1)^{5)}$$

$\triangle m$ = GMの変動量，h = 波高，L_w = 波長，D = 船の静的吃水，BM = メタセンター半径

$\triangle m$は，船が波頂にあるときは負，波底に於ては正，且つ，波頂及び波底で最大値を取る。又前掲条件に於ては，周期的変動をなし，船と波との出会周期に一致する。従つて

$$\triangle m_w = \triangle m \sin pt \qquad 但し \quad P = \frac{2\pi}{T_w} \quad \cdots\cdots (2)$$

$\triangle m_w$ = 船の上下動によるGMの変動

T_w = 船と波との出会周期

次に (1)式を変形して，$\triangle m$と波の Steepness 及び船の長さと波長との関係に就いて考察する。

(i) $\triangle m$ と Steepness

(1) 式に就いて，任意の船の D，BMが決まり，今，$L_w = L_{pp}$の場合に就いて，$X_1 = h/L_w$(Steepness) とおくと，次式を得る。

$$\triangle m = k_1 X_1 \qquad 但し \quad k_1 = \frac{20D}{L_{pp}}\left\{0.42\ BM + 0.07D\right\} \cdots\cdots (3)$$

(ii) $\triangle m$と船の長さ波長比

同様にして，船舶の強度計算に於ける標準波の Steepness，即ち船の長さに等しい波長で波高がこの $\frac{1}{20}$ なる波に就いて，$L_w/L_{pp} = X_2$ とおくと

$$\triangle m = k_2 \times \frac{1}{X_2} \qquad 但し，k_2 = \frac{D}{L_{pp}}\left\{0.42\ BM + 0.07D\right\} \cdots\cdots (4)$$

III GMの周期的変動による船の横動揺

船舶の静水中に於ける無抵抗横動揺の運動方程式は次式で与えられる。

$$I\frac{d^2\theta}{dt^2} + W \cdot GM \cdot \theta = 0 \quad \cdots\cdots (5)$$

I：重心を通る縦軸に対する船体質量慣性モーメント

W：船の排水量

θ：船直軸に対する船の横傾斜角

(5)式に於けるGMに，船の上下動によるGMの周期的変化を考慮すると，(5)式は次の様になる。

$$I\frac{d^2\theta}{dt^2} + w(m + \triangle m_w)\theta = 0 \quad \cdots\cdots (6)$$

$$I\frac{d^2\theta}{dt^2} + wm\left(1 + \frac{\triangle m}{m}\sin pt\right)\theta = 0 \quad \cdots\cdots (6)'$$

(6)式は，Mathieu の方程式であるが，之に就いて $\triangle m_w$ を半周期毎にGMを中心として，$\pm\triangle m$ 変動すると仮定する。(2)式と比較すればこの仮定は，船のGMの変動に対する考察としては，より severe なものであり，従つて安全性に就いては safe side を取ることを意味する。

故に $\dfrac{d^2\theta_1}{dt^2}+\dfrac{wm}{I}\left(1+\dfrac{\triangle m}{m}\right)\theta_1=0 \qquad \dfrac{\pi}{p}>t>0$ ………………… (7)

$\dfrac{d^2\theta_2}{dt^2}+\dfrac{wm}{I}\left(1-\dfrac{\triangle m}{m}\right)\theta_2=0 \qquad \dfrac{2\pi}{p}>t>\dfrac{\pi}{p}$

$\omega^2=\dfrac{wm}{I} \quad \omega_1{}^2=\omega^2\left(1+\dfrac{\triangle m}{m}\right) \quad \omega_2{}^2=\omega^2\left(1-\dfrac{\triangle m}{m}\right)$ とおくと，(7)式の解は，

$$\theta_1=A_1\cos\omega_1 t+B_1\sin\omega_1 t \qquad \text{………………… (8)}$$
$$\theta_2=A_2\cos\omega_2 t+B_2\sin\omega_2 t$$

(8)式の係数 A_1，B_1，A_2 及び B_2 を次の様な条件によつて定める。

$$(\theta_1)_{t=\frac{\pi}{p}}=(\theta_2)_{t=\frac{\pi}{p}} \qquad (\dot\theta_1)_{t=\frac{\pi}{p}}=(\dot\theta_2)_{t=\frac{\pi}{p}} \qquad \text{………………… (9)}$$
$$(\theta_2)_{t=\frac{2\pi}{p}}=s(\theta_1)_{t=0} \qquad (\dot\theta_2)_{t=\frac{2\pi}{p}}=s(\dot\theta_1)_{t=0}$$

(8) を (9) に代入すると，

$$A_1\cos\pi\frac{\omega_1}{p}+B_1\sin\pi\frac{\omega_1}{p}-A_2\cos\pi\frac{\omega_2}{p}-B_2\sin\pi\frac{\omega_2}{p}=0 \qquad \text{…………(10)}$$
$$-A_1\omega_1\sin\pi\frac{\omega_1}{p}+B_1\omega_1\cos\pi\frac{\omega_1}{p}+A_2\omega_2\sin\pi\frac{\omega_2}{p}-B_2\omega_2\cos\pi\frac{\omega_2}{p}=0$$
$$A_1s-A_2\cos2\pi\frac{\omega_2}{p}-B_2\sin2\pi\frac{\omega_2}{p}=0$$
$$B_1s\omega_1+A_2\omega_2\sin2\pi\frac{\omega_2}{p}-B_2\,\omega_2\cos2\pi\frac{\omega_2}{p}=0$$

(10)式が常に成立する為には，係数の行例式は零でなければならない。従つて

$$\begin{vmatrix} \cos\pi\frac{\omega_1}{p} & \sin\pi\frac{\omega_1}{p} & -\cos\pi\frac{\omega_2}{p} & -\sin\pi\frac{\omega_2}{p} \\ -\omega_1\sin\pi\frac{\omega_1}{p} & \omega_1\cos\pi\frac{\omega_1}{p} & \omega_2\sin\pi\frac{\omega_2}{p} & -\omega_2\cos\pi\frac{\omega_2}{p} \\ s & 0 & -\cos2\pi\frac{\omega_2}{p} & -\sin2\pi\frac{\omega_2}{p} \\ 0 & s\omega_1 & \omega_2\sin2\pi\frac{\omega_2}{p} & -\omega_2\cos2\pi\frac{\omega_2}{p} \end{vmatrix}=0 \quad \text{……(11)}$$

之を解くと

$$s_2-2Ns+1=0 \qquad \text{…………………(12)}$$

但し $N=\cos\pi\dfrac{\omega_1}{p}\cos\pi\dfrac{\omega_2}{p}-\dfrac{\omega_1{}^2+\omega_2{}^2}{2\omega_1\,\omega_2}\sin\pi\dfrac{\omega_1}{p}\sin\pi\dfrac{\omega_2}{p}$

又は

$$N=\cos\pi\frac{\omega}{p}\left(1+\frac{\triangle m}{m}\right)^{\frac{1}{2}}\cos\pi\frac{\omega}{p}\left(1-\frac{\triangle m}{m}\right)^{\frac{1}{2}}-\frac{1}{\sqrt{1-\left(\frac{\triangle m}{m}\right)^2}}\sin\pi\frac{\omega}{p}\left(1+\frac{\triangle m}{m}\right)^{\frac{1}{2}}\sin\pi\frac{\omega}{p}\left(1-\frac{\triangle m}{m}\right)^{\frac{1}{2}}$$

(12)式に就いて不安定振動の限界を求める。即ち (9)式より明かな様に，$|S|>1$ なるときは，振動は不安定である。又 $S=\pm1$ 従つて $N=1$ とおいて $\dfrac{\triangle m}{m}$ と $\dfrac{\omega}{p}$ の関係を求める（詳細は力学書に依る）と，第1図の如き限界範囲曲線が得られる。ω/p に就いては，T_s＝船の横動揺周期，T_w を船と波との出会周期とすれば，$T_s=\dfrac{2\pi}{\omega}$，$T_w=\dfrac{2\pi}{p}$ であるから $\omega/p=T_w/T_s$ となる。

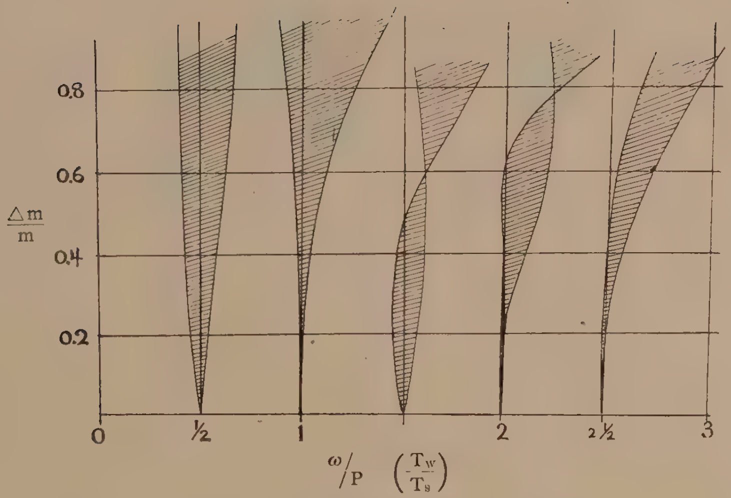


Fig. 1. Diagram for instability of ship's rolling
/////: The critical ranges of period for which the instability of rolling motion occurs.

IV 漁船に於けるGMの変動

次に，実例について，最近竣工したトロール漁船，第36大洋丸[6]及び，鮪延縄漁船，第12海王丸[7]に就いて，その傾斜試験結果を用いて $L_{pp} = L_w$ の波で，Steepness 1/20 の場合の △m，及び △m/m を求めると第1表及び第2表となる。

Table 1. △m/m for No. 36 TAIYO-MARU

Gross tonnage	744,42 tons
Length P. P.	54.95 m
Breadth	9.50 m
Depth	5.09 m

Item No.		1	2	3	4
Condition		Light condition	Full conditions		
			Leaving port	Fishing ground	Arriving port
Mean draft	(m)	2.92	3.85	3.93	3.77
BM	(m)	2.95	2.28	2.24	2.33
GM	(m)	0.587	0.851	0.647	0.531
△m	(m)	0.076	0.086	0.087	0.085
△m/m	(−)	0.129	0.102	0.134	0.160

BM : Metacentric Radius
GM : Metacentric Height
⊿m : The change of GM

Table 2. $\triangle m/m$ for No. 12 KAIO-MARU

Gross tonnage	309.64 tons
Length P. P.	43.34 m
Breadth	7.20 m
Depth	3.60 m

Item No.		1	2	3	4
Condition		Light condition	Full conditions		
			Leaving port	Fishing ground	Arriving port
Mean draft	(m)	1.87	2.97	3.14	2.95
BM	(m)	2.56	1.61	1.53	1.63
GM	(m)	0.70	0.46	0.51	0.51
$\triangle m$	(m)	0.052	0.061	0.063	0.061
$\triangle m/m$	(−)	0.074	0.133	0.123	0.120

更に，$\frac{\triangle m}{m}$ と L_w/L_{pp} 及び Steepness との関係が (3)，(4)式より得られる。即ち 第2，3，4 及び5図となる。

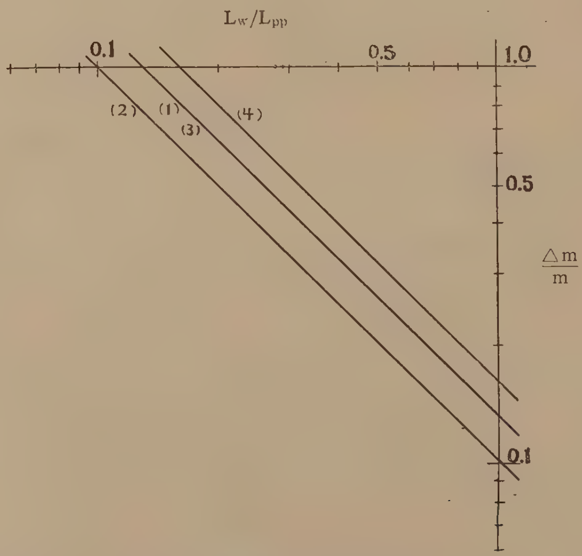


Fig. 2. $\triangle m/m$ for wave and ship's length ratio, No. 36 TAIYO-MARU

(1) $\triangle m/m=0.13\times 1/\ L_W/L_{pp}$ (2) $\triangle m/m=0.10\times 1/\ L_W/L_{pp}$
(3) $\triangle m/m=0.13\times 1/\ L_W/L_{pp}$ (4) $\triangle m/m=0.16\times 1/\ L_W/L_{pp}$

* Numbers in the parentheses in Figs. 2, 3, 4, and 5 correspond to the numbers in Tables, that is, they indicate ship's conditions.

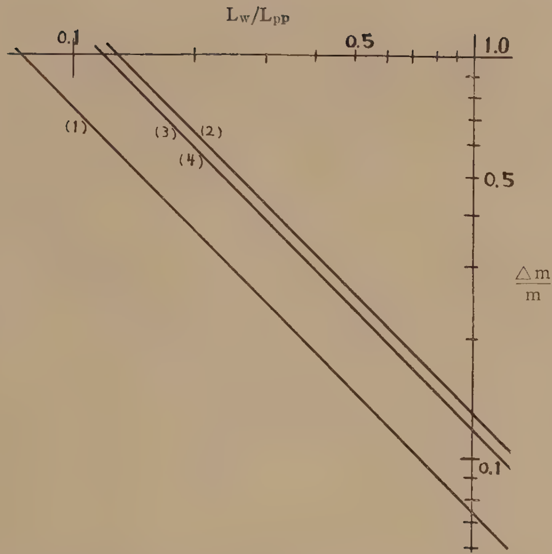


Fig. 3. $\triangle m/m$ for wave and ship's length ratio, No. 12 KAIO-MARU

(1) $\triangle m/m = 0.075 \times 1/\ L_w/L_{pp}$ (2) $\triangle m/m = 0.13 \times 1/\ L_w/L_{pp}$
(3) $\triangle m/m = 0.12\ \times 1/\ L_w/L_{pp}$ (4) $\triangle m/m = 0.12 \times 1/\ L_w/L_{pp}$

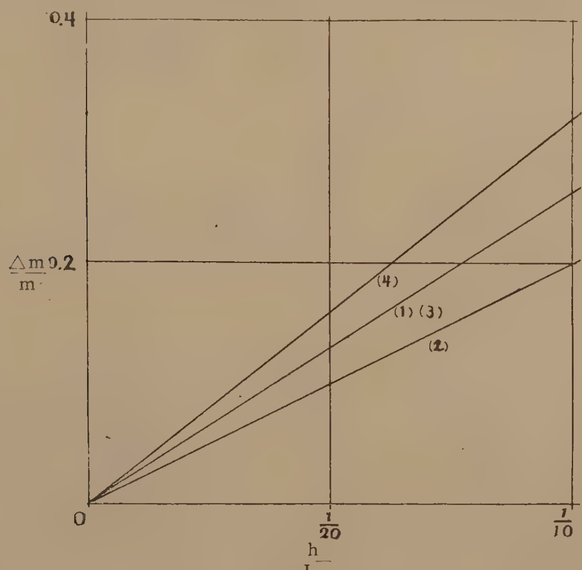


Fig. 4. $\triangle m/m$ for wave steepness, No. 36 TAIYO-MARU

(1) $\triangle m/m = 2.60 \times h/L_w$ (2) $\triangle m/m = 2.00 \times h/L_w$
(3) $\triangle m/m = 2.60 \times h/L_w$ (4) $\triangle m/m = 3.20 \times h/L_w$

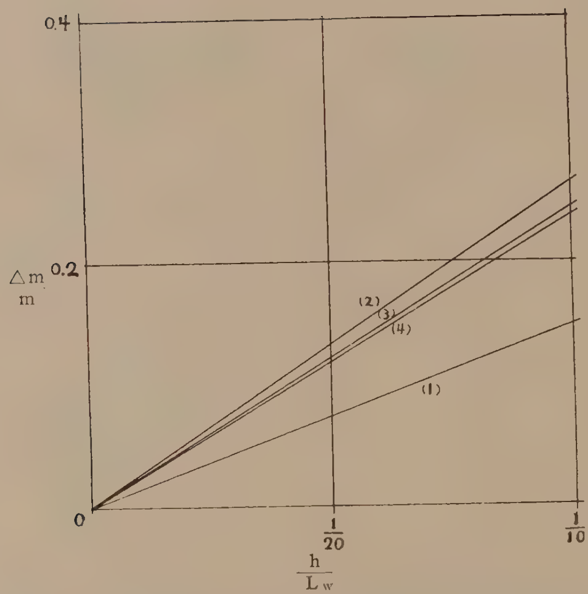


Fig. 5. △m/m for wave steepness, No. 12 KAIO-MARU

(1) $\triangle m/m = 1.49 \times h/L_W$　(2) $\triangle m/m = 2.65 \times h/L_W$
(3) $\triangle m/m = 2.47 \times h/L_W$　(4) $\triangle m/m = 2.40 \times h/L_W$

次に，同船の各状態に於ける T_s を計算する。一般に T_s は次の諸式で与えられる。

$$T_s = 2.01 \frac{cB}{\sqrt{GM}}$$

但し，c[8] に就いては，

Light Condition に於ては　$c = 0.265\,n + 0.273$
Full Condition に於ては　$c = 0.170\,n + 0.229$　$n = D'/B$
鮪延縄漁船では　$D'/D = 1.35$
トロール漁船では　$D'/D = 1.20$

従つて，第3及び4表となる。

Table 3. Rolling period for No. 36 TAIYO-MARU

Item No.	1	2	3	4
Condition	Light condition	Full conditions		
		Leaving port	Fishing ground	Arriving port
Mean draft (m)	2.92	3.85	3.93	3.77
GM (m)	0.587	0.851	0.647	0.531
c (−)	0.443	0.346	0.338	0.355
Ts (sec)	11.0	7.2	8.0	9.2

Ts : Rolling period of ship

Table 4. Rolling period for No. 12 KAIO-MARU

Item No.	1	2	3	4
Condition	Light condition	Full conditions		
		Leaving port	Fishing ground	Arriving port
Mean draft (m)	1.87	2.97	3.14	2.95
GM (m)	0.70	0.46	0.51	0.51
c (−)	0.452	0.359	0.344	0.360
Ts (sec)	8.0	7.6	6.9	7.2

T_w に就ては，IIの(i)で用いた様に $L_w=L_{pp}$ とすると，今所要の波を トロコイド波とすると，T_w は次の式で与えられる。[10]

$$T_w = \sqrt{\frac{\pi}{g}\cdot L_w}$$
$$= \sqrt{\frac{\pi}{g}\cdot L_{pp}}$$

故に，前掲の漁船について T_w を計算すると，

第36大洋丸に対する $T_w = 4.2$ sec. 　　但し $L_w = L_{pp} \fallingdotseq 55$ (m)

第12海王丸に対する $T_w = 3.6$ sec. 　　$L_w = L_{pp} \fallingdotseq 43$ (m)

一方，波の Steepness に就ては，Stokes 波の最も阻しい限度は Michel によると 1/7 であり，観測による最高の波は 1/8 であると云われている。[9] 又航海者が海洋に於て目撃した記録的大浪では $\frac{1}{10}\sim\frac{1}{11}$ である。[10] 且つ，多くの資料の結果として波長と Steepness との関係は次式で与えられる。[2] 即ち第6図となる。

$$\frac{H_w}{L_w}=0.74\frac{1}{L_w^{\frac{1}{2}}}$$

今 $L_w=L_{pp}\fallingdotseq 55$(m) 及び $L_w=L_{pp}\fallingdotseq 43$(m) とおいて第6図より求めると Steepness $\fallingdotseq\frac{1}{10}$ となる。

従つて，以上の諸計算の結果次の事が分る。

(i) $\omega/p=T_w/T_s$ に就いて

第36大洋丸，第3表に於て $T_w=4.2$ Sec. として各状態に於ける T_w/T_s を計算すると Full condition の出港時について，$T_w/T_s \fallingdotseq \frac{1}{2}$，他の場合には，$L_w$ の僅少の増減により $\frac{1}{2}$ に近づく。

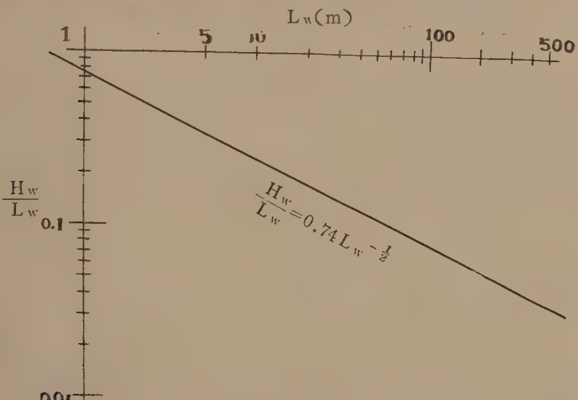


Fig. 6. Wave length and steepness

第12海王丸，第4表に於て $T_w= 3.6$ sec. とすると，Full condition 帰港時 $T_w/T_s = \frac{1}{2}$ となる。

第1図より $T_w/T_s= \frac{1}{2}$ に於て 不安定となることは明かである。

(ii) $\triangle m/m$ に就いて

第1，及び2表により，即ち Steepness $=\frac{1}{20}$ なる場合，両船に対して $\frac{\triangle m}{m}=0.074\sim0.160$ となるから，第1図に於けるこの $\frac{\triangle m}{m}$ の範囲では不安定域は狭いが，$\omega/p=\frac{1}{2}$ 及び $\frac{3}{2}$ で比較的広い範囲をもつ。

Steepness $=\frac{1}{10}$ とすると，第36大洋丸 第4図(2)に於て $\frac{\triangle m}{m}=0.32$ となり最大である。之は，前者に

比して更に広い範囲の不安定域となる。

(iii) L_w/L_{pp} に就いて

(1)式については，$L_w>10\times D$ を条件としている[4] 従つて，L_w/L_{pp} の最小値，即ち $\frac{\triangle m}{m}$ の最大値には限界がある。第36大洋丸，第2図(4)に於て $L_w/L_{pp}>0.53$，故に $\frac{\triangle m}{m}<.031$ 又，第12海王丸，第3図(2)に於て $L_w/L_{pp}>0.43$，故に $\frac{\triangle m}{m}<0.31$ となり，L_w/L_{pp} が増大するにつれて $\frac{\triangle m}{m}$ は減少し，即ち 安定となる。

V 考　　察

このGMの変動の復原性能えの影響は，緒言に於て既に述べた安全示数又は限界線を提示する際に考慮された最も severe な状態に，更にこの dynamical な GM の変動を合せて考慮することによつて明かにされる。G. S. Baker[5] も述べている様に，特に漁船の様な GM の小さな場合には，波頭に於て負となり，若し相当期間最大動揺を続け，更に風が加われば，船は危険状態に陥ると考えられる。

実際船舶に於ては，所要の水域を波浪の方向に直角に航行している場合，危険を伴う様な横動揺は針路を変換する等の処置によつて避け得るとも考えられるが，船舶運航者として T_s を知ることにより横動揺の同調を起す如き波の週期を知ることは勿論であるが，更にこゝに論述した様な不安定動揺を伴う波の週期も知つておかねばならない。

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漁網材料の研究

III. 網糸の抗張力に関する二三の知見 (2)

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Mechanical Studies of Fishing Net Materials

III. Some information on the tensile strength of netting cord (2)

Tetsuo MIURA

Abstract

The relations between the tensile strength and the various sizes of cord were studied and also the values of some attributes of cord were computed. The materials used for this study are 20s/ν/3Z cotton cord (ν is a sign representing various cord numbers) and 250d(15)/ν/3Z amilan cord which were manufactured by the Hakodate Fishing Net Company (in Japan).

The values of the specific gravity and the weight per unit length of the cord of each number were measured as shown in Table 1 and these were taken as the basis of the calculations by which the following results were obtained.

The various kinds of the size of cord — weight per unit length, substantial area of cross-section, diameter of circle corresponding to the above area, strand radius and yarn radius — and the cord number or the total number of yarns, have the relations as given in Table 2. The approximate values of the substantial fineness of the cord of each number were computed from the formulas given in Table 2 as shown in Table 3.

Formerly, Kawai, Terada *et al*[1] have come to a conclusion, in their study on the same relations, as if the weight per unit length and the substantial area of cross-section would be quantities independent of each other. However, this conclusion is contradictory, since the area of cross-section measured by the gravimetric method as adopted by them and the weight per unit length are the same quantities intrinsically. This fact was discussed fully in the present paper.

If it is assumed that the one metre length of No. ν at the intrinsic state of cord weighs G grams which is computed from the following formula —

$G=0.1093\nu$ for the cotton cord

$G=0.0820\nu$ for the amilan cord,

and that the tensile strength and the cord number are in proportion, the relations between the tensile strength and the weight per unit length or the substantial area of cross-section are expressed by the equations of straight line as shown in Table 4.

If the actual measurements of the above quantities are exclusively taken as the basis of consideration, these pairs of variables indicate that a straight line will not fit a set of points satisfactorily and a curve of the type $y=bx^{a}$ will fit a set of points better than the above line. The formulas of this type were expressed as shown in Tables 6 and 7.

The above results, of course, may be appreciably different according to the materials used, but the grounds of discussion are not altered by such a difference.

1 緒　　論

さきに，川合・寺田等[1]は綱の大小と抗張力との関係を実験して，綿綱糸では“(i)抗張力と単位長重量とは60号までは撚の堅弱に関係なく比例し（ii)抗張力と断面積とは堅撚の場合はほぼ比例するが弱撚の場合は比例しない”という結論を下している。然るに，糸の断面積は，同氏等が行つたように比重法で求める場合は，単位長重量と本質的に同じもので，単に数値の違いがあるに過ぎない。従つて，撚の堅弱に関係なく抗張力が単位長重量に比例するものならば断面積にも比例すべきであり，上記の結論には矛盾がある。尚同報告は以上の関係を図示しているだけで実験式を求めていないし，各測定値を載せてないから後で実験式を求めるわけにいかない。その後，長棟[2]及び宮本[3]はそれぞれの著書に乾・湿両状態時における糸の抗張力と単位長重量との実験式を与えているが，勿論測定の方法や数値は示されていない。然るに，糸の単位長重量は，糸の自然の長さの決め方によつて値が異なつてくるので，たとい同一試料であつても実験式中の常数の値が変り得るものである。従つて糸の自然の長さの決め方を示していない実験式については一考を要する。勿論，材料繊維の種類・品質・糸までの製造過程・測定条件等による相違は当然である。

著者は以上の事実を論議した上，綿綱糸については乾湿両状態時ばかりでなく白煮後乾・白煮後湿状態時における同じ関係の実験式を求め，又合成繊維アミランの網糸についても同じ関係式を求め，更に糸の諸属性の数値及びそれら間の関係を算出して綿及びアミラン網糸についての二三の特性を求めたのでここに報告する。

2 供　試　材　料

函館製網K.K.製普通撚綿及びアミラン網糸で，その太さの種類及び構造は次の通りである。詳細は本題第1報[4]に示してある。

綿　　糸　　20s/ 4，6，8，10，12，14，15，16，18，20，/3Z　の10種類

アミラン糸　　250d(15)/ 3，4，5，8，10，12，15，18，20，/3Z　及び 250d(15)/4/4Z　の10種類

3 測　定　方　法

抗　　張　　力：測定方法は第1報[4]に述べてある通りで，その測定値は同報第1，2表に示してある。

糸の自然の長さ：同報にも述べてある通り，単糸1本について1g宛荷重した時の糸の張り方をもつて糸固有の状態とみて，その長さを測ることにした。

単 位 長 重 量：抗張力を測定した後，予め印しておいた糸の自然長50cmの2標線部よりチヤック部の糸片を切り去り，残つた2糸片（つないで50cm長となる）を合せて評量し，その2倍をとつて糸長1mの重量とした。

比　　　　　重：綿繊維の比重は，各号糸について上記 50cm 長の糸30本を1束にし，その重さを空気中及び水中で測つて算出した。但し水中重量は，白煮によつて糸内の気泡を除き引続き二昼夜水中に沈めて吸水させた後水中より取り出さずにそのまま懸垂させて評量した。アミラン繊維の比重は各号について 50cm 長の糸15本を1束とした時の空気中及び水中重量から算出した。白煮は行わない。

試 験 室 状 態：20～24°C，　60～65% R. H.

4 比重及び單位長重量測定値

綿或はアミランの各号糸より測定した夫々の繊維の比重 s と各号糸の単位長重量 G(g/m) の値は第1表の通りである。又表によつて綿及びアミラン糸の号数に対する単位長重量を図示すれば第1図のようになる。

Table 1. The specific gravity s measured and the weight per unit length G of the cord* of each number.

Cotton cord			Amilan cord		
#	s	G (g/m)	#	s	G (g/m)
4	1.533	0.414	3	1.177	0.248
6	1.532	0.632	4	1.165	0.367
8	1.534	0.871	5	1.163	0.400
10	1.529	1.089	** 5.3	1.176	0.400
12	1.529	1.299	8	1.154	0.580
14	1.524	1.523	10	1.155	1.033
15	1.526	1.619	12	1.153	0.997
16	1.520	1.735	15	1.151	1.047
18	1.523	1.995	18	1.110	1.605
20	1.514	2.214	20	1.124	1.580

* 20s/ν/3Z cotton cord and 250d (15)/ν/3Z amilan cord (ν is a sign representing various cord numbers, s count, d denier and Z direction of upper twist).

** See the author's previous report[4] p. 354.

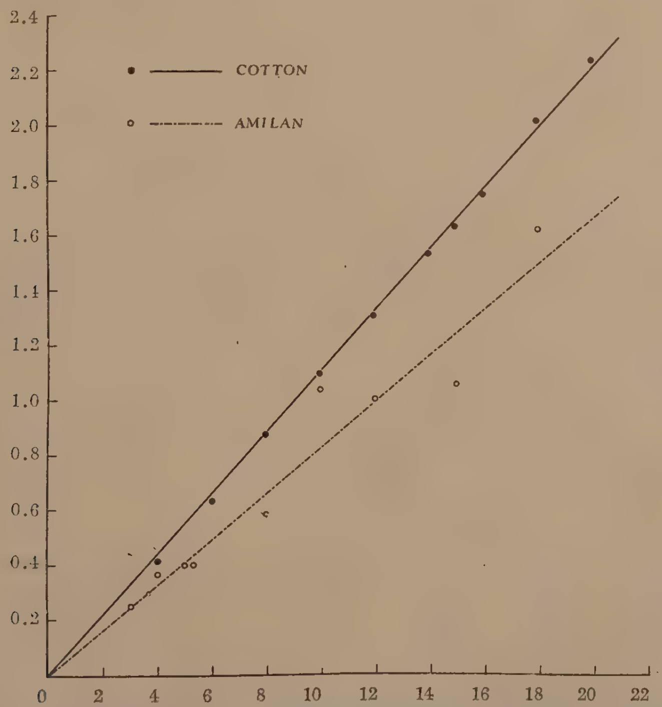


Fig. 1. Weight per unit length of netting cords plotted against cord numbers. The lines are from the formulas (1) and (2). Ordinate—weight per unit length in $g.m^{-1}$; abscissa—cord number.

5　糸の諸属性に関する計算結果と考察

第1図によれば単位長重量と号数とはほぼ比例する。よつて号数に対する単位長重量の回帰関係が原点を通る直線であると仮定し，第1報[4] 354頁の計算順序に従つて単位長重量Gの号数ν(又は単糸数n)に関する母回帰係数βの95%信頼度における信頼区間を算出し，Gとν(又はn) の関係式を求めれば次のようになる。

綿　　糸：標本回帰係数　$b=\sum\nu G/\sum\nu^2=0.1093$

その不偏分散平方根　$u_b=0.0010$

t分布表[5]によれば　$n=N-2=11-2=9$のとき　$t_{0.05}=2.2622$

$\therefore$　$0.1070\leqq\beta\leqq0.1116$　即ち　$\beta=0.1093\pm0.0023$

$\therefore$　$G=(0.1093\pm0.0023)\nu=(0.0364\pm0.0008)n$　(1)

アミラン糸：$b=0.0820$,　$u_b=0.0053$,　$n=9$　のとき　$t_{0.05}=2.2622$

$\therefore$　$0.0700\leqq\beta\leqq0.0940$　即ち　$\beta=0.0820\pm0.0120$

$\therefore$　$G=(0.0820\pm0.0120)\nu=(0.0273\pm0.0040)n$　(2)

(1)，(2)によつて同じ号数の綿糸及びアミラン糸の重量G_cとG_aとを比較すれば

$G_a/G_c\fallingdotseq 0.753\pm0.126$　(3)

但し，この区間は95＋%信頼度におけるものとなる（第1報，357頁参照）・これによればアミラン糸の重さは同じ号数の綿糸の重さの約75%である。

次に綿・アミランの各号糸より得たそれぞれの繊維の比重を考察する。各号糸より求めた値の相違が偶然誤差にのみ起因するとするならば，統計数値表[5]の解説106頁に示されている方法によつて，その母平均の信頼区間が求められる。信頼度を95%にとれば

綿　　糸：標本平均値　$\bar{s}=1.526$　その不偏分散平方根　$u_s=0.006$

$n=N-1=10-1=9$　のとき　$t_{0.05}=2.2622$

$\therefore$　$s=1.526\pm0.004$　(4)

アミラン糸：　$\bar{s}=1.153$,　$u_s=0.021$,　$n=9$　のとき　$t_{0.05}=2.2622$

$\therefore$　$s=1.153\pm0.015$　(5)

上では一応各号糸より求めた比重の値に偶然誤差のみがあると仮定したのであるが，表をよく見れば判る通り，綿繊維の比重は糸が太くなるほど減少の傾向にある。これは糸が太くなるほど脱気が充分に行われなかつたことを意味するものではなかろうか。即ち表の傾向から定誤差があると考えられ，撚糸を試料として繊維の比重を求めた場合には，むしろ細糸より得たものゝ方に信頼性がある。よつて，ここでは綿繊維の比重の値として(4)の上限をとり

$s_c=1.530$　(4)′

ときめる。アミランの場合も各号糸よりの比重値は糸が太くなるほど減少傾向にあるようであるが，この場合は，もともと処理済糸であるため，値の変動が大きく簡単に修正することは危険である。よつてこの場合は(5)の中央値をとり

$s_a=1.153$　(5)′

ときめる。(4)′，(5)′の値は諸文献[6]のものと比較しても大体適当な値である。勿論綿の場合は，繊維の種類・産地によつて違うし又混綿されているから文献の値をそのまま採用するわけにいかない。

糸の実質断面積をA_{mm^2}，糸長1mの重量をWg，繊維の比重をsとすれば$G=sA$であるから，sがきまればAはGから求められる。即ち断面積は，これを比重法によつて求めた場合には，単位長重量とは独立なものではない。故に緒論で述べた通り川合・寺田等の結論には矛盾がある。綿・アミラン繊維の比重を，(4)′，(5)′として，$G=sA$の関係と(1)，(2)の関係式から，綿・アミラン糸の断面積A_{mm^2}とν(又はn)との関係は次のように算出される。勿論誤差は95%信頼度におけるものである。

綿　　糸：　$A=(0.0714\pm0.0015)\nu=(0.0238\pm0.0005)n$　(6)

アミラン糸： $A=(0.0713\pm0.0104)\nu=(0.0238\pm0.0035)n$ (7)

(6)，(7)における係数の信頼区間を比較すればわかる通り，比重法で求めた糸の実質断面積は，20s 単糸でつくられた綿糸と 250d 原糸でつくられたアミラン糸（綿糸と同じ構成の）との間には，有意の差がないことが知られる（単に番手とデニールとの換算では 20s は 266d，250d は 21.3s に相当）。

次に，糸の実質断面を円と仮定した時の撚糸の直径を D_{mm}，片子糸の半径を r_{mm}，単糸の半径を ρ_{mm} とすれば，$A=\frac{\pi}{4}D^2=3\pi r^2=3\pi\rho^2\nu$ の関係と(6)，(7)式とから，D，r と ν（又はn）との関係及び ρ の値が直ちに算出される。その結果と上に求めた結果とをまとめて示せば第2表の通りになる。

Table 2. The relations between the various kinds of the size* of cord and the cord number ν or the total number of yarns n.

Cotton cord	Amilan cord
$G=(0.1093\pm0.0023)\nu=(0.0364\pm0.0008)\,n$	$G=(0.0820\pm0.0120)\nu=(0.0273\pm0.0040)\,n$
$s=1.530$	$s=1.153$
$A=(0.0714\pm0.0015)\nu=(0.0238\pm0.0005)\,n$	$A=(0.0713\pm0.0104)\nu=(0.0238\pm0.035)\,n$
$D=(0.302\pm0.003)\sqrt{\nu}=(0.174\pm0.002)\sqrt{n}$	$D=(0.301\pm0.022)\sqrt{\nu}=(0.173\pm0.013)\sqrt{n}$
$r=(0.087\pm0.001)\sqrt{\nu}=(0.050\pm0.001)\sqrt{n}$	$r=(0.087\pm0.006)\sqrt{\nu}=(0.050\pm0.004)\sqrt{n}$
$\rho=0.087\pm0.001$	$\rho=0.087\pm0.006$

* G=weight per unit length in $g.m^{-1}$, s=specific gravity, A=substantial area of cross-section in sq mm, D=diameter of circle corresponding to A in mm, r=strand radious in mm, ρ=yarn radious in mm.

表によれば 20s 綿撚糸の重量 Ggは，単糸数を n とすれば

$$G=(0.0364\pm0.0008)n \quad (8)$$

となる。宮本[3]はその著書に，川合[7]の行つた試験結果から $G-0.356n$ なる数値を与えている（同著61及び64頁）が，これは誤植か計算違ひであろう。(8)において下の限界をとれば $G=0.0356n$ となり，丁度1桁違つている。

尚参考のため撚糸各号の単位長重量 Gg/m，断面積 A_{mm^2}，直径 D_{mm} 及び片子糸の半径 r_{mm} を算出してみれば第3表の如くなる。

Table 3. The approximate values of the substantial fineness of the cord of each number, computed from the formulas given in Table 2.

Cotton cord					Amilan cord				
#	G g/m	A sq mm	D mm	r mm	#	G g/m	A sq mm	D mm	r mm
4	0.437	0.286	0.604	0.174	3	0.246	0.214	0.521	0.151
6	0.656	0.428	0.740	0.213	4	0.328	0.285	0.602	0.174
8	0.874	0.571	0.854	0.246	5	0.410	0.357	0.673	0.195
10	1.093	0.714	0.955	0.275	5.3	0.435	0.378	0.693	0.200
12	1.312	0.857	1.046	0.301	8	0.656	0.570	0.851	0.246
14	1.530	1.000	1.130	0.326	10	0.820	0.713	0.952	0.275
15	1.640	1.071	1.170	0.337	12	0.984	0.856	1.043	0.301
16	1.749	1.142	1.208	0.348	15	1.230	1.070	1.166	0.337
18	1.967	1.285	1.281	0.369	18	1.476	1.283	1.277	0.369
20	2.186	1.428	1.351	0.389	20	1.640	1.426	1.346	0.389

6 糸の抗張力と單位長重量又は断面積との関係 (1)

著者は第1報[4]において，糸の抗張力と号数とが比例するものと仮定して糸の乾・湿その他の状態時における抗張力と号数との関係式を求めたが，もし前項のように単位長重量又は断面積と号数とが比例するものと仮定するならば，抗張力と単位長重量又は断面積とはこれ又比例すべきである。ところで綿糸の単位長重量と号数との関係図(第1図)において，最適合直線よりの各点の偏奇は一応偶然誤差のみによるとみて (1)式を得たのであるが，図をよく見れば判るように，概して号数の小なる点は直線より下に，大なる点は直線の上にある。このことは各点の偏奇が単に偶然誤差のみによるものでないことを意味する。この試験においては，糸の自然の長さをきめるのに，単糸1本について 1g宛荷重したときの糸の張りを自然とみて，その状態において長さを測つたのであるが，もし号数の小なるうちは単糸1本について 1gより少な目に，号数の大なるときは 1gより大き目に荷重し，かくて直線上に点がよくのるように糸固有の長さをきめることが出来たと仮定すれば，(1)式の信頼誤差は更に小さくなるであろう。換言すれば糸の長さのきめ方いかんによつて単位長重量と号数との比例関係は良くもなり悪くもなる。しかも糸の自然の長さというものを本質的に定義することは不可能である。

よつて今，糸固有の長さを適当に定めることにより，単位長重量と号数とは完全に比例し，しかも $G=0.1093\nu$ なる関係を充したとしよう。逆にいえば，$G=0.1093\nu$ で与えられる重量をもつ糸の長さを ν 号糸の1mと定義するのである。一方綿繊維の比重を $s=1.530$ ときめるならば，必然的に綿糸の断面積 A_{mm2}は $A=0.0714\nu$ ときまる。アミラン糸の場合には，これが処理済糸であるため，勿論以上のような考察を許さないが，綿糸と同様に取扱つて，$G=0.0820\nu$，$s=1.153$ 従つて $A=0.0713\nu$ ときめる。即ちGもAも予め定めておく。然るときは，第1報[4]の抗張力と号数との関係式と，以上の関係式とから，抗張力と単位長重量又は断面積との関係が直ちに算出される。その結果は第4表の通りである。

Table 4. The relations* between the cord tensile strength in kg R in various conditions and the weight per unit length in g.m^{-1} G or the substantial area of cross-section in sq mm A, expressed with the 95% confidence error.

Condititions	Cotton cord	Amilan cord
Dry	$R_1=(12.9\pm0.7)\ G$	$R_1=(30.7\pm4.3)\ G$
	$=(19.7\pm1.1)\ A$	$=(34.8\pm4.8)\ A$
Wet	$R_2=(14.7\pm1.1)\ G$	$R_2=(25.1\pm3.1)\ G$
	$=(22.4\pm1.7)\ A$	$=(28.4\pm3.5)\ A$
Dry after boiling	$R_3=(13.3\pm0.9)\ G$	
	$=(20.3\pm1.4)\ A$	
Wet after boiling	$R_4=(13.8\pm0.9)\ G$	
	$=(21.0\pm1.3)\ A$	

* It has been assumed that the one metre length of No. ν at the intrinsic state of cord weighs G grams which is computed from the following formula — $G=0.1093\ \nu$ for the cotton cord and $G=0.0820\ \nu$ for the amilan cord —, and that the tensile strength and the cord number are in proportion.

7 糸の抗張力と單位長重量又は断面積との関係 (2)

前項においては，抗張力と号数とは比例するものと仮定し，綿糸では $G=0.1093\nu$ アミラン糸では $G=0.0820\nu$ で与えられる重さをもつ糸の長さを ν 号糸の 1mときめ，計算によつて抗張力と単位長重量又は断面積との関係を求めたのであるが，これらの仮定や考察を排して実測値だけをもとにした場合はどうなるであろうか。

第1報，第1図をよく見れば判るように，目立つほどではないが概して号数の小なるR点は最適合直線よ

り上に，号数の大なるR点は下になつている。一方単位長重量と号数との関係においては目立つほどでないが概して号数の小なるG点は最適合直線より下に，号数の大なるG点は上になつている。従つてRとGとの関係図をつくつて見ると，上の二性質が重なり合つてGの小なるR点は最適合直線より上に，Gの大なるR点は下にかなりはつきり現われてくる。よつて単位長重量又は断面積のような糸の属性を一般にMで表すとき，RとMとの関係としては，原点を通る直線と仮定するよりもより一般的に

$$R=bM^{a} \qquad (a,\ b\text{は常数}) \tag{9}$$

なる式をあてはめた方が近似性が高いようである。前項の場合は誤差をMの係数だけにもたせようとし，この場合は誤差をMの係数と指数とに分担させたことになる。前者は実用的に便利な形であるが，仮定を必要とする。後者は実用的には不便であるが，実験値をもとにしている。何れにしろ，測定の範囲内（糸の太さの）では大同小異であるが，将来更に太い糸についても試験する予定であるから，(9)式を仮定した場合の結果も次に求めておこう。まずその計算順序を一般的に示しておく。

(9)式より $\log R=\log b+a\log M$

ここで $\log R=Y,\quad \log M=X,\quad a=\beta_1,\quad \log b=\beta_0$ とおけば

$$Y=\beta_0+\beta_1 X \tag{10}$$

となる。故にこの二変量X, Yにおいて，Xに対するYの回帰関係が直線であると仮定して 0 次，1 次の母回帰係数を推定する方法を考える。

統計数値表[5] 109頁に示された回帰係数検定法はYの標本値y_iは上の母回帰直線の周りに等しい分散σ^2の正規分布をしており，又Xの標本値x_iは固定している場合であるが，糸の属性としての変量X, Yは二元正規分布に従うものとしてよいからy_iはこの仮定を満足する。

今X, Yの分散及び共分散を夫々V_x, V_y, C_{xy}で表わすならば1次の標本回帰係数$b_1=C_{xy}/V_x$，残差平方和$\varDelta=N(V_y-b_1C_{xy})$，又$u^2=\varDelta/N-2$とおけば$b_1$の不偏分散$V_{b1}{}^2=u^2/NV_x$で計算される。そして

$$F=\frac{(b_1-\beta_1)^2}{V_{b1}{}^2} \qquad \begin{array}{ll}(b_1-\beta_1)^2 \text{ の自由度} & n-1\\ V_{b1}{}^2 \text{ の自由度} & n=N-2\end{array}$$

はF分布をなし，その平方根はt分布をする。

$$t=\frac{b_1-\beta_1}{V_{b1}} \qquad n=N-2$$

それで Prob $\{|t|<t_{\alpha1}\}=\beta_1$ を満足する t_α を t 分布表によつて求め得たとすれば

$$|t|<t_{\alpha1} \qquad \text{即ち} \qquad \left|\frac{b_1-\beta_1}{V_{b1}}\right|<t_{\alpha1}$$

をβ_1に関して解いて，信頼度$(1-\alpha_1)\times 100\%$の信頼区間として

$$b_1-t_{\alpha1}\cdot V_{b1}\leqq\beta_1\leqq b_1+t_{\alpha1}\cdot V_{b1} \tag{11}$$

を得る。標本から定めた回帰直線は

$$y'=b_0+b_1(x-\bar{x}) \qquad b_0=\frac{1}{N}\Sigma y_i$$

で，理論的回帰直線は

$$Y=\beta_0+\beta_1 x=\beta_0+\beta_1\bar{x}+\beta_1(x-\bar{x})$$

今 $\gamma=\beta_0+\beta_1\bar{x}$

とおけば $t=\dfrac{b_0-\gamma}{u}\sqrt{N} \qquad n=N-2$

はt分布をする。それで Prob $\{|t|<t_{\alpha0}\}=\beta_0$ なる如き $t_{\alpha0}$ を表より求めたとすれば

$$|t|<t_{\alpha0} \qquad \text{即ち} \qquad \left|\frac{b_0-\gamma}{u}\sqrt{N}\right|<t_{\alpha0}$$

をγに関して解いて

$$b_0-t_{\alpha0}\frac{u}{\sqrt{N}}\leqq\gamma\leqq b_0+t_{\alpha0}\frac{u}{\sqrt{N}}$$

$$b_0-t_{\alpha0}\frac{u}{\sqrt{N}}-\beta_1\bar{x}\leqq\beta_0\leqq b_0+t_{\alpha0}\frac{u}{\sqrt{N}}-\beta_1\bar{x}$$

今 β_1 の信頼限界を　$\beta_{1\,min} \leqq \beta_1 \leqq \beta_{1\,max}$　の如く表せば
信頼度 $(1-\alpha_0)\times 100$(以上の) %の信頼区間として

$$b_0 - t\alpha_0 \frac{u}{\sqrt{N}} - \beta_{1\,max}\bar{x} \leqq \beta_0 \leqq b_0 + t\alpha_0 \frac{u}{\sqrt{N}} - \beta_{1\,min}\bar{x} \qquad (12)$$

即ち，この推定法では β_0 の信頼区間は β_1 とは独立に定まらない。従つて信頼度も $(1-\alpha_0)\times 100$ 以上の%というように確定的に宣言出来ないが，α_0 と α_1 とを，その間に甚だしい差がないようにとるならば，$\beta_{1\,max}$, $\beta_{1\,min}$ を含む項の，β_0 の信頼誤差に及ぼす影響は小さいから，今後(12)式の信頼度を示すのにいちいち“以上の”と断らないことにする。

以上の推定法により抗張力と単位長重量の関係を計算すれば次のようになる。

綿　　糸：

気乾状態のとき　$V_x=0.04862$,　$V_y=0.04095$,　$C_{xy}=0.04453$
$b_1=0.91579$,　$\varDelta=0.00171$,　$u=0.01461$,　$V_{b1}=0.02095$
$\alpha_1=0.051$ にとれば　$n=N-2=8$ のとき　$t_{0.05}=2.3060$
故に(9)式により95%信頼度で　$0.8675 \leqq \beta_1 \leqq 0.9641$
又 $b_0=\bar{y}=1.20114$,　$\bar{x}=0.07848$,　$\alpha_0=\alpha_1=0.05$　にとれば
(10)式により95%信頼度で　$1.1148 \leqq \beta_0 \leqq 1.1437$
∴　$Y=(0.9158\pm 0.0483)X+(1.1293\pm 0.0144)$

湿潤状態のとき　$V_x=0.04862$,　$V_y=0.04308$,　$C_{xy}=0.04537$
$b_1=\bar{y}=0.93319$,　$\varDelta=0.00736$,　$u=0.00092$
$V_{b1}=0.04350$,　$0.8329 \leqq \beta_1 \leqq 1.0335$
又　$b_0=\bar{y}=1.26171$,　$\bar{x}=0.07848$
$1.1585 \leqq \beta_0 \leqq 1.2185$
故に95%信頼度で
$Y=(0.9332\pm 0.1003)X+(1.1885\pm 0.0300)$

白煮後乾燥状態のとき　$V_x=0.04862$,　$V_y=0.03628$,　$C_{xy}=0.04195$
$b_1=0.86285$,　$\varDelta=0.00079$,　$u=0.00991$
$V_{b1}=0.01421$,　$0.8301 \leqq \beta_1 \leqq 0.8956$
又　$b_0=\bar{y}=1.22269$,　$\bar{x}=0.07848$
$1.1452 \leqq \beta_0 \leqq 1.1648$
故に95%信頼度で
$Y=(0.8629\pm 0.0328)X+(1.1550\pm 0.0098)$

白煮後湿潤状態のとき　$V_x=0.04862$,　$V_y=0.03847$,　$C_{xy}=0.04314$
$b_1=0.88731$,　$\varDelta=0.00192$,　$u=0.01550$,
$V_{b1}=0.02223$　$0.8361 \leqq \beta_1 \leqq 0.9386$
$b_0=\bar{y}=1.23351$,　$\bar{x}=0.07848$
$1.1486 \leqq \beta_0 \leqq 1.1792$
故に95%信頼度で
$Y=(0.8873\pm 0.0513)X+(1.1639\pm 0.0153)$

アミラン糸：

気乾状態のとき　$V_x=0.07434$,　$V_y=0.06083$,　$C_{xy}=0.06551$
$b_1=0.88128$,　$\varDelta=0.03091$,　$u=0.00386$
$V_{b1}=0.07209$　$0.7150 \leqq \beta_1 \leqq 1.0475$
$b_0=\bar{y}=1.35512$,　$\bar{x}=-0.16364$
$1.4812 \leqq \beta_0 \leqq 1.5175$

故に95%信頼度で

$Y=(0.8813\pm0.1662)X+(1.4993\pm0.0181)$

湿潤状態のとき　$V_x=0.07434$,　$V_y=0.06233$,　$C_{xy}=0.06630$

$b_1=0.89182$,　$\Delta=0.03204$,　$u=0.06328$

$V_{b1}=0.07339$

$0.72226\leqq\beta_1\leqq1.0611$

$b_0=\bar{y}=1.26390$,　$\bar{x}=-0.16364$

$1.3914\leqq\beta_0\leqq1.4283$

故に95%信頼度で

$Y=(0.8918\pm0.1692)X+(1.4098\pm0.0185)$

以上の結果をまとめて第5表を得る。

Table 5. Equations of the best straight lines through the points in fig. 2, expressed with the 95% confidence errors.

Cotton cord	Amilan cord
$Y_1=(0.9158\pm0.0483)X+(1.1293\pm0.0144)$	$Y_1=(0.8813\pm0.1662)X+(1.4993\pm0.0181)$
$Y_2=(0.9332\pm0.1003)X+(1.1885\pm0.0300)$	$Y_2=(0.8918\pm0.1692)X+(1.4098\pm0.0185)$
$Y_3=(0.8629\pm0.0328)X+(1.1550\pm0.0098)$	
$Y_4=(0.8873\pm0.0513)X+(1.1639\pm0.0153)$	

* Y_1 = log. dry strength in kg, Y_2 = log. wet strength, Y_3 = log. dry after water boiling strength, Y_4 = log. wet after water boiling strength,　X = log. weight per unit length in g.m.$^{-1}$

これによつてRとGとの両対数関係に対する最適合直線を引けば第2(a～f)図の如くなる。

第5表から各回帰係数の信頼区間を比較すればすぐ判る通り95%信頼度において，綿糸では，気乾時における0次回帰係数（直線のY軸上における截辺）が他の状態時におけるそれらと有意差があるだけで，他の状態時における0次回帰係数間には有意差がなく，又1次回帰係数（直線の方向係数）間にはどの二つをとつても有意差が認められない。アミラン糸では両状態時で0次回帰係数には有意差があるが，1次回帰係数には有意差がない。綿糸とアミラン糸の間ではどの状態時の場合を比較しても0次回帰係数間には有意差があるが1次回帰係数間には有意差がない。

次に第5表において，$Y=\log R$, $X=\log G$　として逆対数をとればRとGとの関係が得られる(第6表)。

Table 6. The relations* between the tensile strength in kg R and the weight per unit length in g. m^{-1} G, expressed with the 95% confidence errors.

Cotton cord	Amilan cord
$R_1=(13.43\pm0.45)\,G^{(0.916\pm0.048)}$	$R_1=(31.60\pm1.32)\,G^{(0.881\pm0.166)}$
$R_2=(15.47\pm1.07)\,G^{(0.933\pm0.100)}$	$R_2=(25.72\pm1.09)\,G^{(0.892\pm0.169)}$
$R_3=(14.29\pm0.32)\,G^{(0.863\pm0.033)}$	
$R_4=(14.59\pm0.51)\,G^{(0.887\pm0.051)}$	

* These have based on the actual measurements only (cf. Table 4).

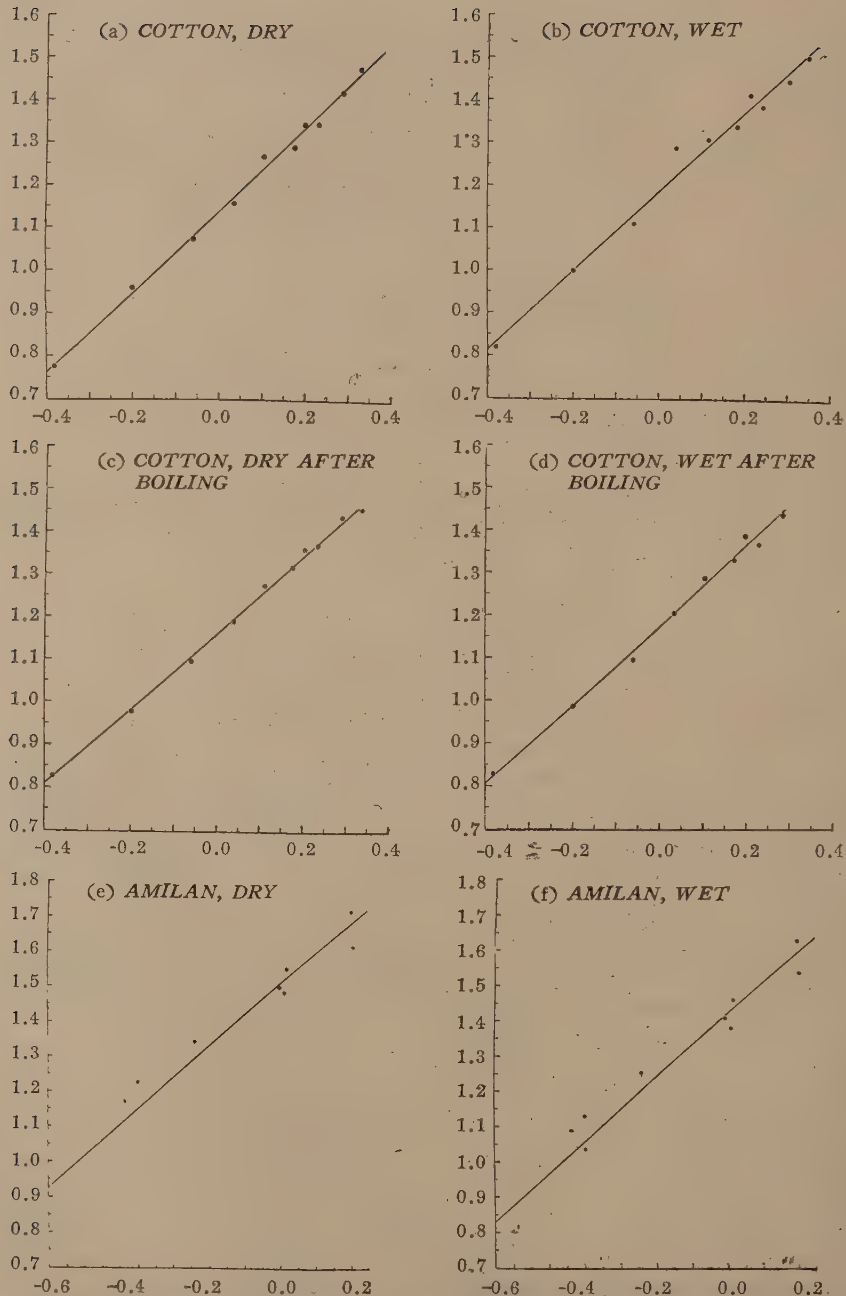


Fig. 2(a—f). Logarithms of tensile strengths of netting cords plotted against logarithms of weights per unit length. The lines are fitted from the formulas given in Table 5. Ordinate—log.tensile strength in kg; abscissa—log.weight per unit length in $g.m.^{-1}$

又綿糸及びアミラン糸の比重を夫々 $s_c=1.530$, $s_a=1.153$ ときめれば単位長重量と断面積との間に綿糸では $G=1.530A$, アミラン糸では $G=1.153A$ の関係があるから，これを第6表のGに入れて抗張力と断面積との関係が得られる(第7表)。

Table 7. The relations* between the tensile strength in kg R and the substantial area of cross-section in sq. mm A.

Cotton cord	Amilan cord
$R_1=(19.91\pm1.07)\ A^{(0.910\pm0.048)}$	$R_1=(46.23\pm5.18)\ A^{(0.881\pm0.166)}$
$R_2=(23.10\pm2.57)\ A^{(0.933+0.100)}$	$R_2=(37.79\pm4.31)\ A^{(0.892\pm0.169)}$
$R_3=(20.64\pm0.76)\ A^{(0.863\pm0.033)}$	
$R_4=(21.31\pm1.22)\ A^{(0.887\pm0.051)}$	

* These were calculated from the formulas given in Table 6 and the specific gravity of cord ($s=1.530$ in cotton, $s=1.153$ in amilan).

第6又は7表によつて知られる通り，この試験で採用したような，糸の自然長のきめ方をもとにした実測値そのまゝを用いるときは，G(又はA) の指数を1としてよいのは，95%信頼度においてアミラン糸と湿潤状態時の綿糸の場合である。しかしこの場合は本来の性質としてよりも，点のばらつきが大きく，従つて信頼誤差が大きいためであろう。糸の太さについての測定範囲が大きくなればなるほど (9) 式が適合してゆくものと思われる。現在の測定範囲では6項によるも7項によるも大差はなく，むしろ6項による方が実用的には便利であろう。

8 要　　結

函館製網 K.K.製普通撚の 20s/ν/3Z 綿網糸及び 250d(15)/ν/3Z アミラン網糸 (ν：号数) を試料とし，糸の諸属性の数値及びそれら間の関係，乾・湿その他の状態時における糸の抗張力と太さとの関係等を求めた。そのうちの二三については，すでに他の研究者により発表されているが，それらの報告とは異なる結論に達したものもある。

(1)糸の単位長重量と号数(又は単糸数)とはほぼ比例する。その比例常数の値は第2表に示してある。綿糸の場合，糸長1mの重量Ggは，単糸数をnとすれば

$$G=(0.0364\pm0.0008)n$$

で与えられる。宮本はその著書[3]の61・64頁に $G=0.356n$ なる値を示しているが，これは明らかに桁違いであろう。尚試料としたアミラン糸の重量は，同号の綿糸のそれの約75%である。

(2)糸の断面積は，これを比重法で求める以上は単位長重量と本質的に同じものである。網糸をつくる繊維の比重には，測定の上修正を加えて第2表に示す値を採用した。この値と G, ν (又はn) 間の関係式とから，糸の断面積 A_{mm^2}, 断面を真円とみたときの直径 D_{mm} 及び片子糸の半径 r_{mm} 等と ν (又はn) との関係を導き，更に単糸の半径 ρ_{mm} も算出した。その結果，20s 単糸で構成された綿糸と 250d 原糸で構成されたアミラン糸との間では，太さについての有意差がないことが知られた (単に番手とデニールとの換算では，20s は 266d, 250d は 21.3s に相当)。

(3)抗張力Rが ν (又はn) に比例すると仮定するならば，上の各条によりGにも従つて又Aにも比例すべきである。川合・寺田等[1]は，GとAとを，Rとの比例関係において，あだかも独立の量であるかのような結論を出しているが，これは正しくない。

(4)綿糸については $G=0.1093\nu$, アミラン糸については $G=0.0820\nu$ で与えられる重量Ggをもつ糸の長さをν号糸の1mときめ，それぞれの繊維の比重としては第2表に示した値を採用し，Rとν (又はn) とが比例するとすれば，RとG (又はA) との関係は第4表で示される。

(5)RとGとの実測値だけをもとにした場合は，これらが互に比例すると仮定するよりも　$R=bM^a$（MはG, Aなど他の属性）なる曲線を適合させた方が近似度が高い。糸の太さについての測定範囲が大きくなるほど，この傾向を示してゆくと思われる。この形式の実験式は第6・7表に示してある。現在の測定範囲では第4表によるも第6・7表によるも大差がない。実用的には第4表の方が便利であろう。

以上は現在の測定範囲（糸の太さについての）内での結果で，将来更に太い糸も含めた結果を出したいと考えている。変量の母平均を推定する場合はすべて信頼度を95%にとつた。勿論試料の母集団が変れば算出した諸数値も若干異なつてくるであろうが，論点には変りがない。

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